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DRAFT FINAL

Remedial Action Plan for Vadose Zone Soils at Building 8200 Fort Carson, Colorado

Prepared For

The US Army Environmental Center
Aberdeen Proving Ground, Maryland

Fort Carson
Colorado Springs, Colorado

and

Air Force Center for Environmental Excellence
Brooks Air Force Base
San Antonio, Texas

March 1997

PARSONS ENGINEERING SCIENCE, INC.
1700 Broadway, Suite 900 • Denver Colorado 80290

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DRAFT FINAL
REMEDIAL ACTION PLAN
FOR VADOSE ZONE SOILS
AT BUILDING 8200
FORT CARSON, COLORADO

Prepared for

US Army Environmental Center
Aberdeen Proving Ground, Maryland

Fort Carson
Colorado Springs, Colorado

and

Air Force Center For Environmental Excellence
Brooks Air Force Base, Texas

March 1997

Prepared by:

Parsons Engineering Science, Inc.
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Denver, Colorado 80290

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SECTION 1

INTRODUCTION

This remedial action plan (RAP) presents the scope for an expansion of the pilot-scale bioventing system in the vicinity of Building 8200 at Fort Carson, Colorado. The purpose of the expanded bioventing system will be to better achieve *in situ* treatment of fuel-contaminated vadose zone soils at the site. The activities related to the installation of the proposed expanded system will be performed by Parsons Engineering Science, Inc. (Parsons ES) for Fort Carson, the US Army Environmental Center (USAEC), and the Air Force Center for Environmental Excellence (AFCEE) Technology Transfer Division (ERT) under AFCEE contract F41624-92-D-8036, 0017. The primary objectives of the bioventing system upgrade are to:

- Deliver oxygen to contaminated vadose zone soils targeted for remediation, to continue aerobic *in situ* remediation of fuel-contaminated soils;
- Provide additional characterization data for site closure; and
- Sustain aerobic *in situ* biodegradation until hydrocarbon-contaminated soils within the unsaturated zone are remediated to below acceptable regulatory standards.

A bioventing pilot test was performed by Parsons ES at Building 8200 from July 15 through August 7, 1996 to determine if *in situ* bioventing would be a feasible cleanup technology for the fuel-contaminated soils within the unsaturated zone. A radius of oxygen influence (RI) of at least 25 feet within the less permeable shallow soils, and a RI of at least 50 feet within the more permeable deeper soils, was observed at the site. Additional detail on the pilot test procedures and results are presented in the Interim Bioventing Pilot Test Results Report for Building 8200 (Parsons ES, 1996) and are summarized in Section 3.

This RAP addresses soil contamination thought to be associated with fuel releases from the Building 8200 site. Four 20,000-gallon underground storage tanks (USTs), formerly used to store gasoline and diesel fuel, were removed in November 1996. Tank removal information indicates that the fuel pipeline connections at the USTs and near the former fuel islands are likely the major source of petroleum contamination at the site. Site investigation data indicate that the majority of soil contamination in the vicinity of Building 8200 is "smear zone" contamination. Smear zone contamination results when free-phase petroleum hydrocarbons sorb to soils near the groundwater surface. Smearing occurs as a result of fluctuations in the groundwater surface elevation. It appears that a significant release of petroleum hydrocarbons from near the former diesel and gasoline tanks and associated piping adjacent to Building 8203 has resulted in significant downgradient smear zone contamination, affecting soils in the vicinity of Building 8200.

Pilot test data have been used to design the expanded bioventing system to remediate contaminated soils. The expanded system will consist of the three existing air injection vent wells (VWs) (VW1, VW2 and VW3) and four newly constructed VWs to deliver oxygen throughout the remaining areas of unsaturated fuel-contaminated soils. A horizontal VW (VW3), installed by Parker Excavating, Inc. during the tank removal project, was constructed within the tank excavation, prior to backfilling. Five new vapor monitoring points (MPs) also will be constructed to monitor soil gas for contaminant reduction and oxygen influence. The expanded bioventing system will target smear zone contamination as well as vadose zone contamination.

unsaturated

This document is divided into eight sections, including this introduction, and one appendix. Section 2 discusses the site background and includes a discussion of existing characterization data. Section 3 provides the results of the pilot test conducted at Building 8200. Section 4 identifies the treatment area of the proposed expanded system; provides construction details for the expanded system; and recommends a proven, cost-effective approach for the remediation of the remaining hydrocarbon-contaminated soils at the site. Procedures for handling investigation-derived waste are described in Section 5, and Fort support requirements are listed in Section 6. Section 7 provides key points of contact at Fort Carson, USAEC, AFCEE, and Parsons ES; and Section 8 provides the references cited in this document. A design package for the expanded bioventing system is provided in Appendix A.

SECTION 2

SITE BACKGROUND

2.1 SITE HISTORY

Fort Carson is located in El Paso County approximately 8 miles south of Colorado Springs, Colorado and covers approximately 220 square miles. The installation, established in 1942 as a training facility, is assigned to the Fourth Infantry Division (Mechanized). The principal industrial operations at the Fort have been repair and maintenance of vehicles and aircraft (ICF Kaiser Engineers, 1992).

Unless otherwise noted, this section is summarized from a draft site assessment report prepared by RUST Environment & Infrastructure (RUST, 1994). Building 8200, also known as the Vehicle Maintenance Facility, is used for vehicle maintenance and repair, vehicle storage, and the refueling of military vehicles. Building 8200 is located approximately 140 feet south of Building 8203 and a former underground fuel storage area (Figure 2.1). The site is level, and the portions of the site south of the perimeter fence are paved with concrete. Areas north of the site are vegetated with grasses. Buildings 8200 and 8203 are set on concrete slab-on-grade foundations.

In November 1996, all four 20,000-gallon steel underground storage tanks (USTs) immediately east of Building 8203 were removed by Parker Excavating, Inc. All four tanks, installed in 1987, passed leak-detection testing in September 1991; however, site investigations performed in 1992 and 1994 indicated the presence of petroleum hydrocarbon contamination at the site (RUST, 1994). Three of the former tanks had contained diesel fuel, and one had contained unleaded gasoline. The excavation to remove the tanks was approximately 70 feet x 45 feet and 16 feet deep and was backfilled with clean, sandy fill. Approximately 1,800 cubic yards of soil was removed from the excavation; however, soils at the bottom and sides of the excavation were still visibly contaminated and smelled of fuel. The fuel pipelines were properly abandoned in place (Parker Excavating, 1997). The "as-built" location of the fuel pipelines is uncertain, however, interpretation of existing design drawings is approximated on Figure 2.1 (Cloonan, 1997).

2.2 SITE GEOLOGY AND HYDROGEOLOGY

Because the bioventing technology is applied primarily to unsaturated soils, this section describes soils at and above the shallow aquifer. A more detailed discussion of the geology and hydrogeology can be found in the *Bioventing Pilot Test Work Plan for Building 8200* (ES, 1996b).

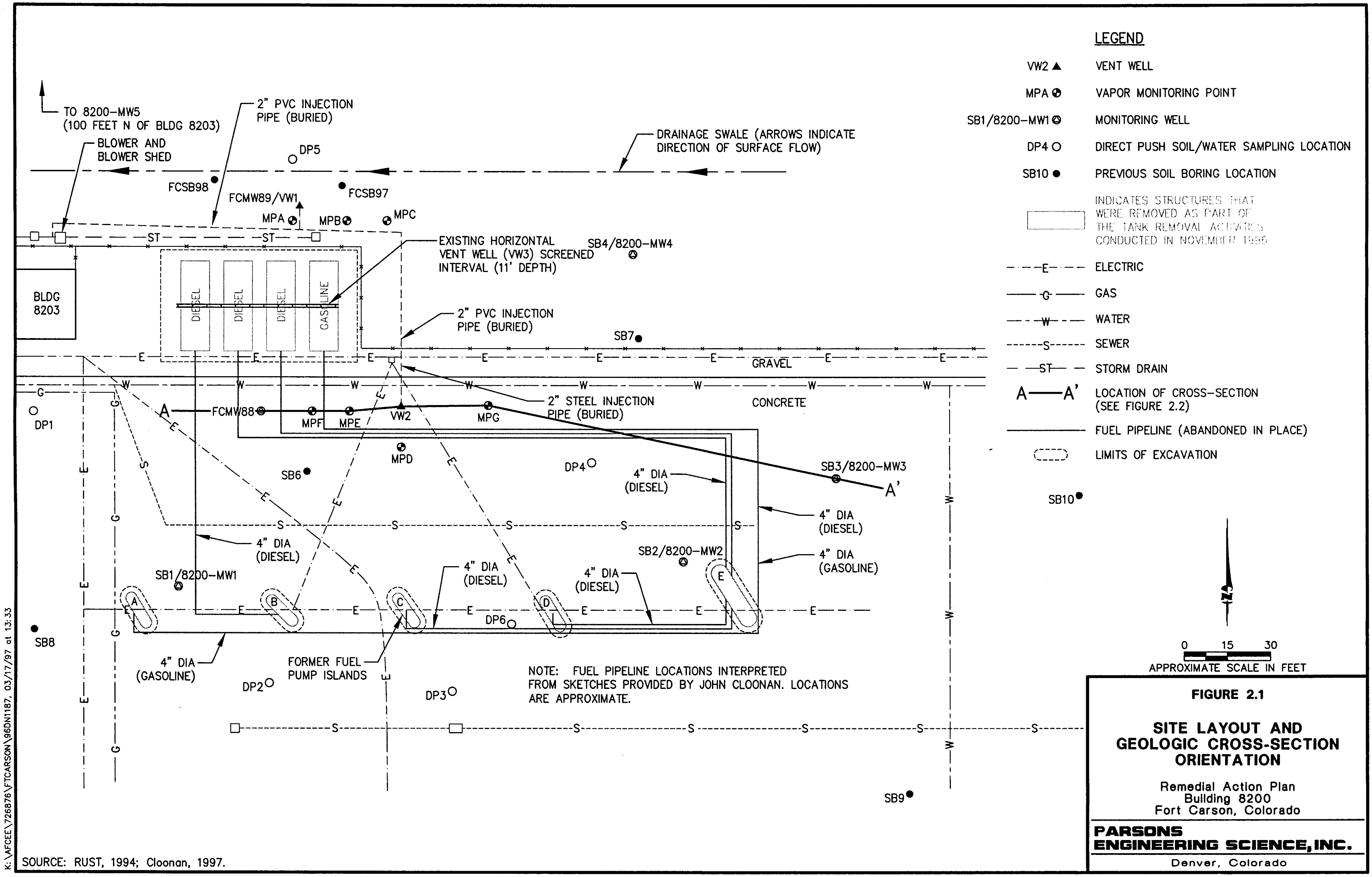


FIGURE 2.1

SITE LAYOUT AND GEOLOGIC CROSS-SECTION ORIENTATION

Remedial Action Plan
Building 8200
Fort Carson, Colorado

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

Fort Carson is situated between the Great Plains and Southern Rocky Mountain physiographic provinces, and is characterized by dissected plains and terraces with local relief ranging from 10 to 50 feet. The topography of the easternmost area of Fort Carson is characterized by low, easterly dipping plains which are dissected on the east by Fountain Creek. The Fort is underlain by soils derived from Quaternary floodplain, glacial, alluvial, and colluvial deposits, and weathered bedrock. The Quaternary deposits, ranging in thickness up to 100 feet, are comprised of fine-grained clays and silts with some intercalated sandy silts and sandy clays. Underlying the Quaternary sediments is Pierre Shale bedrock consisting of interbedded dark gray sandy shales and mudstones with shaley sandstones and siltstones (RUST, 1994).

Unsaturated soils in the vicinity of Building 8200 are primarily dense, brittle silt and clay overlying siltstone bedrock. The unconsolidated soils are approximately 16 to 20 feet thick at the site. In the vicinity of MPA, MPB, and MPC, perched groundwater is encountered at a depth of approximately 18 to 20 feet below ground surface (bgs). Groundwater was measured in VW2 at a depth of approximately 19.2 feet bgs following VW construction in August 1996. Based on lithological observations made at VW2 and each MP, groundwater at the site appears to be perched in the more permeable soil intervals. At MPD, MPE, and MPF perched groundwater is present at a depth of approximately 16 to 17 feet bgs, and the saturated perched zone is approximately 1 to 2 feet thick. The groundwater surface becomes shallower in the direction of 8200-MW3 (Figure 2.1). Groundwater was measured in monitoring well 8200-MW3 (MW3) at a depth of approximately 9.5 feet bgs during July 1996. Not enough groundwater surface data is available to determine the groundwater flow direction at the site. Figure 2.2 is geologic cross-section A-A' (traced on Figure 2.1) of the pilot test site at Building 8200 constructed using data from the bioventing system installation and previous investigations. The interpreted soil profile is shown along with photoionization detector (PID) readings of headspace volatile organic compounds; VW, MW, and MP screened intervals; and total extractable petroleum hydrocarbon (TEPH)/total volatile petroleum hydrocarbon (TVPH) concentrations from laboratory analyses of soil samples.

2.3 SITE CONTAMINANTS

The primary soil contaminants at this site are fuel-related petroleum hydrocarbons. The likely source of the contamination was the UST outlet (elbow) connection and/or associated piping (including pipe joints and pumpstand connections). Tank removal investigations indicated that the tanks were removed in good condition, and that petroleum contamination was observed throughout the tank excavation and around the removed pump islands (Madsen, 1996). Previous investigations by ICF Kaiser Engineers (1992) and RUST (1994) indicated the presence of significant contamination north, south, and southeast of the former tanks. To better define the full areal extent (FAE) of petroleum contamination, two zones of hydrocarbon contamination at the site are identified. Vadose zone hydrocarbon contamination associated with releases from the piping near the tanks or near the pump islands has been defined; however, near the perched groundwater surface, smearing of hydrocarbons released from the site has made vertical definition of the FAE more difficult. Consequently, the discussion on soil hydrocarbons in this report is presented as two separate issues (vadose zone and smear zone contamination).

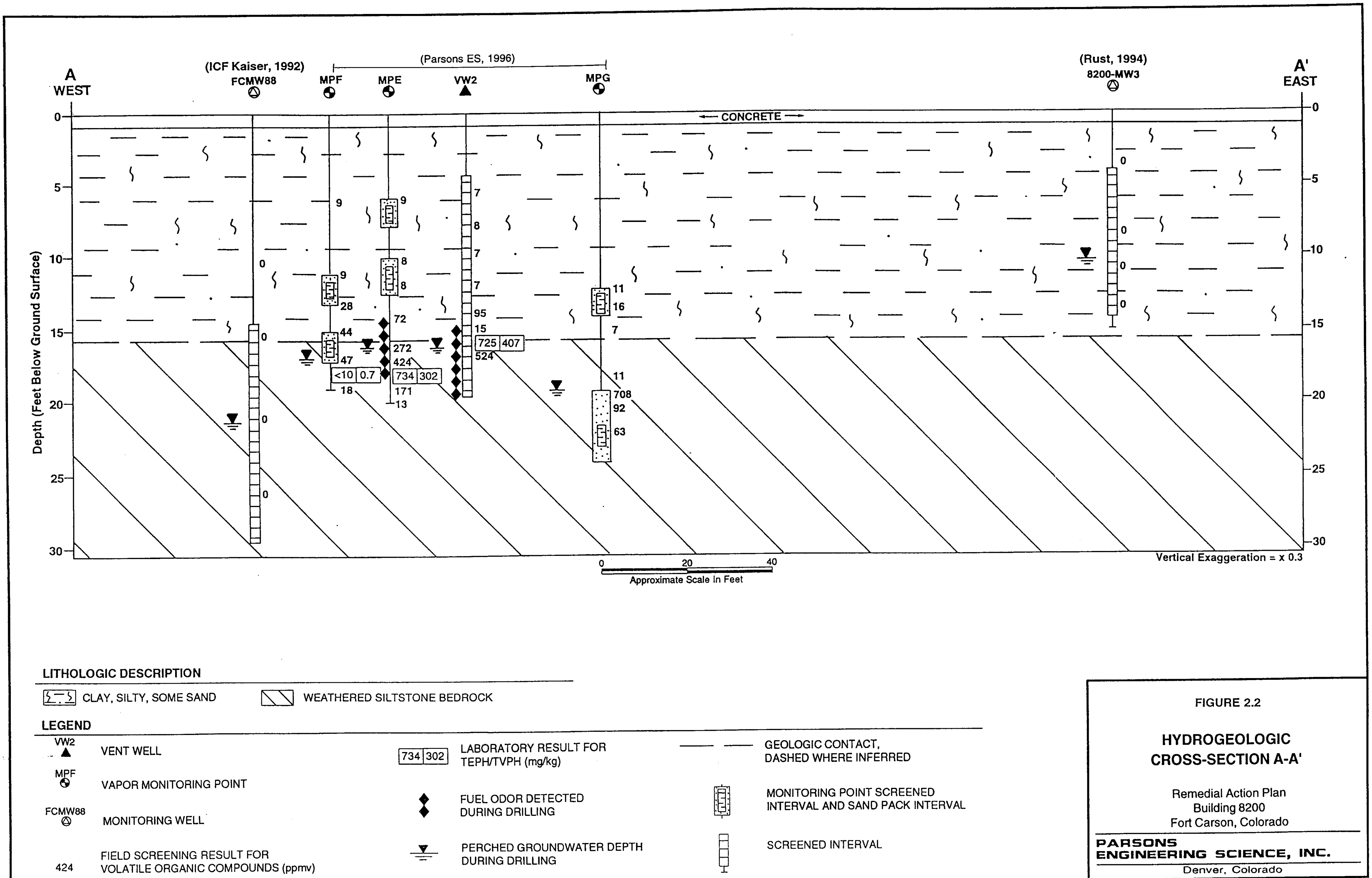


FIGURE 2.2

HYDROGEOLOGIC CROSS-SECTION A-A'

Remedial Action Plan
Building 8200
Fort Carson, Colorado

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

The Colorado Department of Public Health and Environment (CDPHE) has recommended soil cleanup guidelines for petroleum contaminated soils (Colorado Department of Labor and Employment [CDLE], Oil Inspection Section [OIS], 1995). CDLE has established three Remedial Action Categories (RACs) for petroleum contaminated sites. RAC I criteria apply to sites where there is petroleum contamination of groundwater currently being used or has the potential to be used as a public or private drinking water supply; or groundwater within 500 feet or within the zone of influence of a private drinking water-supply well. RAC II criteria apply to sites where there is petroleum contamination of groundwater which has the potential for being used as a private drinking water supply; or groundwater not included in the RAC I designation such as petroleum contamination of groundwater not within 500 feet or within the zone of influence of a private water well. RAC III includes, but is not limited to, groundwater not being used and with little or no potential for being used as a public or private drinking water supply (CDLE, [OIS], 1995). RAC guidelines for total benzene, toluene, ethylbenzene, and xylenes (BTEX) and TPH for each category are provided in Table 2.1.

RAC II guidelines have been assumed to apply to the Building 8200 soils. The RAC II guideline for total BTEX is 50 milligrams per kilogram (mg/kg), and the guideline for TPH is 250 mg/kg. Petroleum hydrocarbon concentrations in site vadose zone soil exceeding CDPHE (1995) RAC II soil cleanup guidelines are bounded by soil borings MPC, MW4, SB7, MW3, DP3, DP2, SB8, and DP1 (Figure 2.1). The horizontal FAE of vadose zone contamination has not been completely defined, however. Areas north, northwest, and east of the former tanks; between soil boring DP4 and well MW3; south of well MW3; near pump island D; south of pump island A; and between well MW1 and boring SB6 require further characterization (Figure 2.1). Figure 2.3 shows the analytical results for BTEX [US Environmental Protection Agency (EPA) Method SW8020]; TEPH, TVPH, and total chromatographable organics (TCO) (EPA Method SW8015M); and oil and grease (O&G) (413.2) analyses for each vadose zone soil sampling location to date. During the bioventing pilot-scale system installation, the highest TEPH and TVPH results for vadose zone soil were 865 mg/kg and 486 mg/kg, respectively, in the sample collected at a depth of 16-17 feet bgs at VW2.

Figure 2.4 shows the analytical results for each smear zone soil sampling location. Smear zone petroleum contamination has been detected as far east as soil boring SB10. At SB10 at a depth of 10 to 13 feet bgs, TCO and O&G were detected at concentrations of 550 mg/kg and 256 mg/kg, respectively. At MW3 at 10 to 13 feet bgs, TCO and O&G were detected at concentrations of 1,700 mg/kg and 900 mg/kg, respectively. Benzene was not detected in either of these samples. During drilling activities for the bioventing pilot test, hydrocarbon-contaminated soils were encountered between approximately 13 and 20 feet bgs near VW2 and between 20 and 24 feet bgs near VW1. Groundwater at VW1 and VW2 was measured at depths of 14.5 feet bgs and 19 feet bgs, respectively.

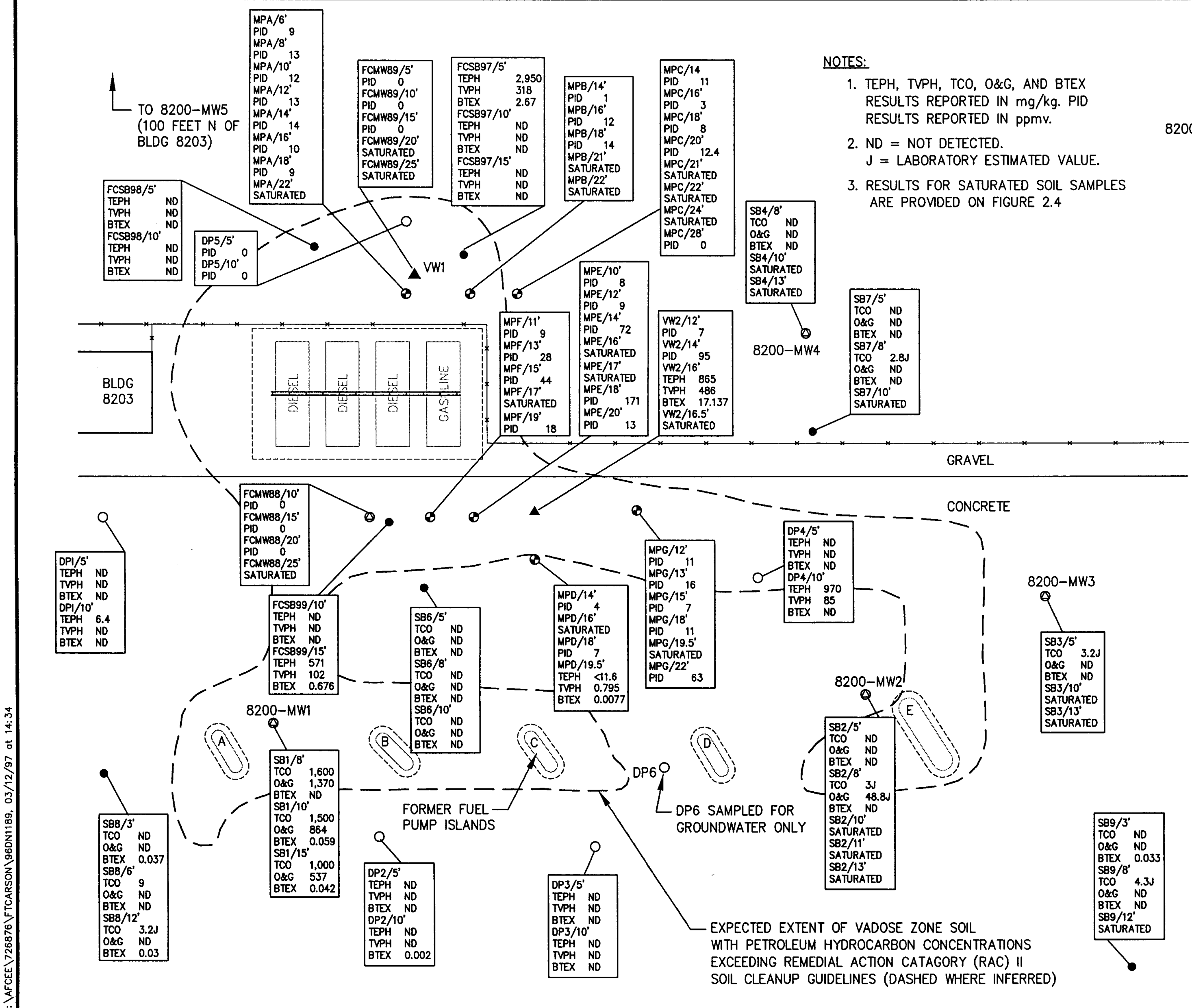
Results of all soil sampling conducted to date indicate that petroleum contamination in soils is concentrated near utility lines, fuel lines, the former tanks and pump islands, and the perched groundwater, which represent source areas or preferential flow paths in the dense, low-permeability silty clay soils at the site. Field observations, field screening results, and soil and soil gas analytical results indicate that site soils are contaminated below 13 feet bgs south and southeast of the former tanks, and below 20

TABLE 2.1
CDPHE SOIL CLEANUP GUIDELINES [a]
REMEDIAL ACTION PLAN
BUILDING 8200
FORT CARSON, COLORADO

Remedial Action Category	Guideline for Total BTEX (mg/kg) [b/c]	Guideline for TPH (mg/kg) [d]
I	20	100
II	50	250
III	100	500

[a] CDPHE = Colorado Department of Public Health and Environment.
[b] BTEX = Benzene, toluene, ethylbenzene, and xylenes.
[c] mg/kg = Milligrams of constituent per kilogram of soil.
[d] TPH = Total petroleum hydrocarbons.

Source: Colorado Department of Labor and Employment, Oil Inspection Section, 1995.



NOTES:

1. TEPH, TVPH, TCO, O&G, AND BTEX RESULTS REPORTED IN mg/kg. PID RESULTS REPORTED IN ppmv.
2. ND = NOT DETECTED.
   J = LABORATORY ESTIMATED VALUE.
3. RESULTS FOR SATURATED SOIL SAMPLES ARE PROVIDED ON FIGURE 2.4

LEGEND

VW2 ▲	VENT WELL
MPA	VAPOR MONITORING POINT
8200-MW1	GROUNDWATER MONITORING WELL
DP4 ○	DIRECT PUSH SOIL/WATER SAMPLING LOCATION
SB10 ●	PREVIOUS SOIL BORING LOCATION
VW2/16'	SAMPLE ID/DEPTH (FEET BELOW GROUND SURFACE)
TEPH	TOTAL EXTRACTABLE PETROLEUM HYDROCARBONS (SW8015M)
TVPH	TOTAL VOLATILE PETROLEUM HYDROCARBONS (SW8015M)
TCO	TOTAL CHROMATOGRAPHABLE ORGANICS (SW8015M)
O&G	OIL AND GREASE (413.2)
BTEX	BENZENE, TOLUENE, ETHYLBENZENE, AND TOTAL XYLENES (SW8020)
PID	PHOTOIONIZATION DETECTOR READING
	APPROXIMATE LIMITS OF EXCAVATION

FIGURE 2.3

ANALYTICAL AND FIELD SCREENING RESULTS FOR VADOSE ZONE SOILS

Remedial Action Plan
Building 8200
Fort Carson, Colorado

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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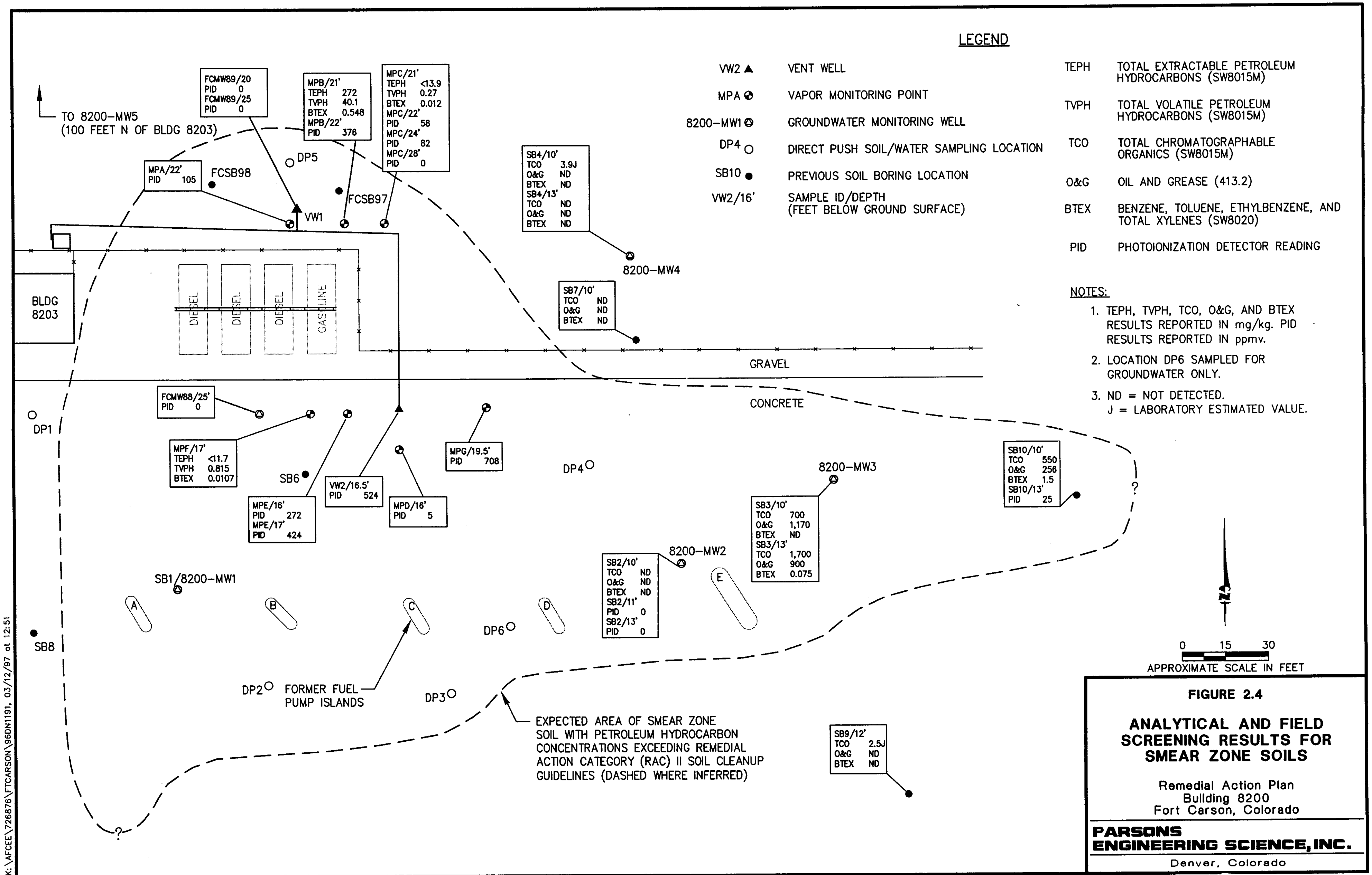


FIGURE 2.4

ANALYTICAL AND FIELD SCREENING RESULTS FOR SMEAR ZONE SOILS

Remedial Action Plan
Building 8200
Fort Carson, Colorado

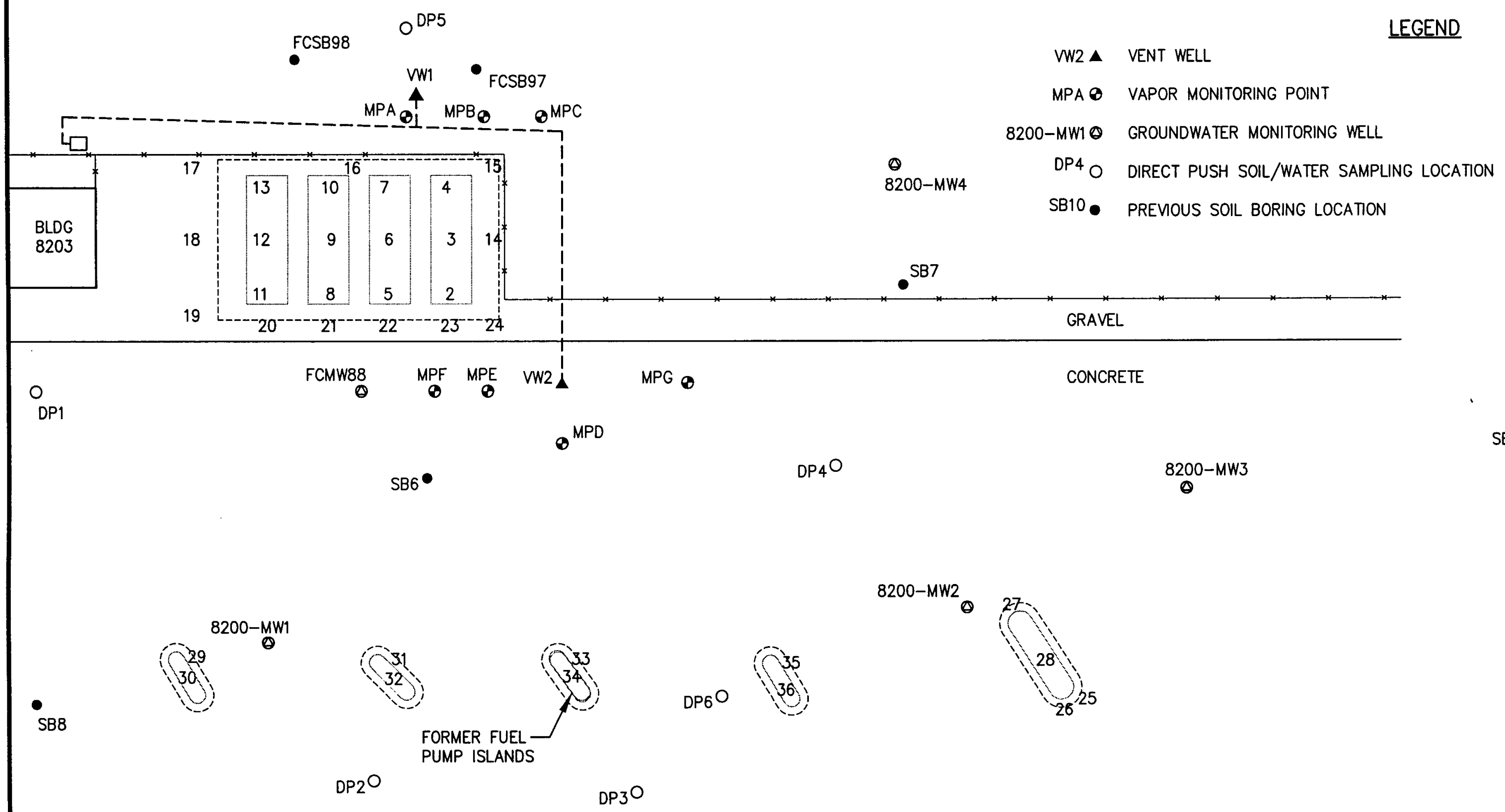
PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

feet bgs north of the former tanks. This indicates that free-phase petroleum hydrocarbons released from near the tank area migrated vertically to the perched groundwater interval, and then spread downgradient along the groundwater surface. Fluctuating groundwater elevations have caused a smearing of petroleum hydrocarbons near the groundwater surface.

Laboratory analysis of soil and soil gas samples indicated the presence of hydrocarbon contamination in most of the boreholes advanced during installation of the pilot-scale bioventing system. The maximum contaminant levels in soil gas were detected at VW2 and MPF-12. Soil gas results by EPA Method TO-3 for MPF-12 were 48,000 parts per million, volume per volume (ppmv) total volatile hydrocarbons (TVH) referenced to jet fuel (jf), 56 ppmv benzene, 26 ppmv toluene, 7.8 ppmv ethylbenzene, and 5 ppmv total xylenes. Soil gas results for VW2 were 24,000 ppmv TVH-jf, 94 ppmv benzene, 20 ppmv toluene, 4.3 ppmv ethylbenzene, and 15 ppmv total xylenes. Soil analytical results are summarized on Figures 2.3 and 2.4.

During tank removal operations at Building 8200 in November 1996, 35 soil samples were collected from the bottom of the excavation, and near each of the five removed pump islands (Parker Excavating, Inc., 1997). Laboratory analytical results for soil samples collected during tank removal activities are presented in Figure 2.5. The samples were analyzed for TVPH and TEPH by EPA Method SW8015M, and for BTEX by EPA Method SW8020. All the soil samples contained detectable amounts of one or more analyte, with the exception of location 24. Within the tank excavation, TVPH concentrations ranged from not detected (ND) in sample 24 to a maximum of 1,700 mg/kg in sample 13; and TEPH concentrations ranged from ND in sample 24 to a maximum of 8,600 mg/kg in sample 9. Within the pump island excavations, TVPH concentrations ranged from not detected (ND) in samples 26 and 27 to a maximum of 490 mg/kg in sample 25; and TEPH concentrations ranged from 3.5 mg/kg in sample 26 to a maximum of 9,900 mg/kg in sample 25. The highest total BTEX concentration (26.6 mg/kg) was detected in sample 23 at a depth of 4 feet bgs, and the highest benzene concentration (2.6 mg/kg) was detected in sample 5 at a depth of 16 feet bgs. Only six soil samples contained detectable amounts of benzene.

Because previous investigations have not fully defined the horizontal or vertical extent of soil contamination at Building 8200, additional soil sampling should be performed during future site investigation field work to be conducted by Foothills Engineering Consultants. Preliminary recommended borehole locations are provided in Section 4. Borehole locations may need to be relocated based on additional information gathered during expanded bioventing system installation activities.



LEGEND

VW2 ▲	VENT WELL
MPA	VAPOR MONITORING POINT
8200-MW1	GROUNDWATER MONITORING WELL
DP4 ○	DIRECT PUSH SOIL/WATER SAMPLING LOCATION
SB10 ●	PREVIOUS SOIL BORING LOCATION
18	TANK REMOVAL SOIL SAMPLING LOCATION
TEPH	TOTAL EXTRACTABLE PETROLEUM HYDROCARBONS (SW8015M)
TVPH	TOTAL VOLATILE PETROLEUM HYDROCARBONS (SW8015M)
BTEX	BENZENE, TOLUENE, ETHYLBENZENE, AND TOTAL XYLENES (SW8020)
	LIMITS OF EXCAVATION

NOTES:

1. TEPH, TVPH, AND BTEX RESULTS REPORTED IN mg/kg.
2. ND = NOT DETECTED.
3. ft bgs = FEET BELOW GROUND SURFACE.

SAMPLING LOCATIONS	DEPTH (ft bgs)	BTEX	TVPH	TEPH
2	16	1.22	150	2,000
3	16	4.86	850	2,700
4	16	21.20	1,100	6,000
5	16	12.33	410	140
6	16	1.96	37	34
7	16	16.43	870	3,300
8	16	7.31	310	1,100
9	16	23.00	1,400	8,600
10	16	21.96	1,000	5,700
11	16	1.00	430	2,100
12	16	9.75	860	5,600
13	16	24.20	1,700	7,900
14	5	0.06	4.5	8.5
15	5	ND	37	170
16	5	0.02	4.3	28
17	5	0.02	1.7	5.4
18	5	ND	2.7	980

SAMPLING LOCATIONS	DEPTH (ft bgs)	BTEX	TVPH	TEPH
19	5	0.01	1.0	9.8
20	4	0.16	150	420
21	4	0.02	4.8	59
22	4	0.14	80	1,400
23	4	26.57	560	91
24	5	ND	ND	ND
25	3	3.45	490	9,900
26	3	ND	ND	3.5
27	3	0.01	ND	7.5
28	3	0.04	16	69
29	3	0.19	59	520
30	3	4.69	190	1,900
31	3	0.45	75	5,400
32	3	0.17	270	1,700
33	3	0.10	230	4,600
34	3	0.12	83	6,700
35	3	ND	8.9	4.7
36	3	0.02	8.1	14

SOURCE: PARKER EXCAVATING INC, 1997

FIGURE 2.5

TANK REMOVAL SOIL SAMPLING LOCATIONS (1996)

Remedial Action Plan
Building 8200
Fort Carson, Colorado

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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SECTION 3

BIOVENTING PILOT TEST RESULTS

An initial bioventing pilot test was performed by Parsons ES from July 15 to August 5, 1996. The objectives of the initial bioventing pilot test at Building 8200 were to:

- Assess the potential for supplying oxygen throughout the contaminated soil profile;
- To determine the rate at which indigenous microorganisms will degrade petroleum hydrocarbons when stimulated by oxygen-rich soil gas at this site; and
- To evaluate the potential for sustaining these rates of biodegradation until hydrocarbon contamination is remediated below regulatory approved standards.

Because bioventing has been demonstrated to be a feasible technology for this site, the pilot test data were used to design an expanded-scale remediation system (Section 4) to remediate the vadose zone soils at the site, to minimize potential releases to groundwater/surface water, and to assure that contaminant levels throughout the site are below regulatory standards (CDLE, 1995).

3.1 PILOT TEST CONFIGURATION

The pilot-scale bioventing test system installation was completed by Parsons ES in August 1996 at Building 8200, and consisted of two air injection VWs (VW1 and VW2) and seven multi-depth MPs. The pilot-test location and configuration were based on available site investigation data (ICF Kaiser, 1992; RUST, 1994), which indicated that the highest TPH contamination was in areas adjacent to (north and southeast of) the former USTs. As shown on Figure 2.1, groundwater monitoring well FCMW89 was converted for use as VW1 and VW2 was installed immediately southeast of the former USTs. Three MPs (MPA, MPB, and MPC) were installed near VW1, and four MPs (MPD, MPE, MPF, and MPG) were installed near VW2. The seven MPs were installed at varying distances from the VWs to monitor *in situ* biodegradation rates and to determine the RI and pressure response resulting from air injection at the two VWs. Existing groundwater monitoring wells 8200-MW1 through -MW5 and FCMW88 were also used as vapor MPs. Monitoring well 8200-MW5 was used as the background MP for the pilot test (Figure 2.1). The horizontal VW (VW3), installed by Parker Excavating during the tank removal project in November 1996, was constructed within the tank excavation prior to backfilling. A 55-foot length of 2-inch diameter PVC pipe with slots manually cut into the pipe was reportedly placed at a depth of approximately 11.0 feet bgs. The screen is set within a 2-foot pea gravel interval, with Visqueen® (plastic) liner placed approximately 1 foot above the horizontal screen (Madsen, 1996). VW3 was connected to the existing blower on January 24, 1997, and was set to inject air at a flow rate of approximately 30 standard cubic feet per minute (scfm). Site-specific construction details for the VWs, MPs, and monitoring wells installed at Building 8200 are presented in Table 3.1.

A fixed, 2.0-horsepower (HP) Gast® regenerative blower unit (model R5) was installed at Building 8200 for the extended pilot test on 5 August 1996. At the time of installation, the blower unit was injecting approximately 1 scfm of ambient air into each of the VWs (VW1 and VW2). Because of frequent power outages in the area, the blower may not have been operating during the period between August 7 and November 22, 1996. The blower was rewired on December 16, 1996, so that the blower restarts automatically following a power outage. The unit is powered via an electrical line that runs to the blower from a power source inside Building 8203 (Figure 2.1). Parsons ES personnel provided an operations and maintenance (O&M) data collection sheet and blower maintenance manual to Ft. Carson personnel in August 1996.

3.2 INITIAL SOIL GAS CHEMISTRY

Prior to initiating air injection, soil gas in the two VWs, all MPs, and each of the existing onsite groundwater monitoring wells was analyzed for initial oxygen, carbon dioxide, and TVH concentrations, as described in the technical bioventing protocol document (Hinchee *et al.*, 1992). Initial oxygen levels were depleted (less than 5 percent), and carbon dioxide (CO_2) levels were elevated (5.3 to 14.0 percent) in soil gas samples from the two VWs, MPD-10, MPD-18, MPF-12, MPG-13, 8200-MW1, and 8200-MW2. In contrast, soil gas from the background MP (well 8200-MW5 located approximately 100 feet north of the site) contained oxygen at a concentration of 19.8 percent and CO_2 at a concentration of 1.4 percent. These initial levels indicated that oxygen depletion and CO_2 accumulation was the result of biodegradation of hydrocarbon contaminants rather than naturally occurring organic matter and abiotic processes. The initial soil gas chemistry results measured at Building 8200 in July 1996 are summarized in Table 3.2.

3.3 *IN SITU* BIODEGRADATION RATES

In situ respiration testing was conducted as part of the initial bioventing pilot test to determine the biodegradation rates of indigenous bacteria in contaminated subsurface soils. The test was performed by injecting ambient air (20.8 percent oxygen) at a rate of approximately 1 scfm into the unsaturated VW2 and MP (MPD-10, MPD-18, and MPG-13) screened intervals for at least 16 hours in order to oxygenate surrounding soils. After air injection was stopped, oxygen, CO_2, and TVH levels in soil gas at the screened intervals were monitored for 11 days. Table 3.3 provides a summary of the oxygen utilization and fuel degradation rates.

Oxygen loss measured at VW2, MPD-10, MPD-18, and MPG-13 occurred at slow rates, ranging from 0.01 percent per hour at MPG-13 to 0.06 percent per hour at VW2. At VW2, the oxygen dropped from 20.8 percent to 14.0 percent in 10 days (14,580 minutes). Based on these oxygen utilization rates, an estimated 20 to 80 mg of fuel per

TABLE 3.1
VENT WELL AND MONITORING POINT CONSTRUCTION SUMMARY
REMEDIAL ACTION PLAN
BUILDING 8200
FORT CARSON, COLORADO

Location	Total Borehole Depth (feet bgs) [a]	Screened Interval (feet bgs)	Sand Pack Interval (feet bgs)
FCMW88	30.0	14.5-29.5	10.5-30.0
FCMW89 (VW1)	25.0	9.5-24.5	6.5-25.0
8200-VW2	19.5	4.5-19.5	4.0-19.5
8200-VW3 (horizontal)	11.0	55 linear feet	10-12
8200-MPA	22.0	16.0, 19.0	15.5-16.5, 18.5-19.5
8200-MPB	22.0	15.5, 20.0	15.0-16.0, 19.5-20.5
8200-MPC	24.0	15.0, 23.0	14.0-16.0, 22.0-24.0
8200-MPD	20.5	10.0, 18.0	8.0-12.0, 16.0-20.5
8200-MPE	20.0	7.0, 11.0	6.0-8.0, 10.0-12.5
8200-MPF	19.0	12.0, 16.0	11.0-13.0, 15.0-17.0
8200-MPG	24.0	13.0, 22.0	12.0-14.0, 19.0-24.0
8200-MW1	20.0	5.8-15.8	3.3-20.0
8200-MW2	18.5	7.6-17.6	6.0-18.5
8200-MW3	15.0	4.1-14.1	3.0-15.0
8200-MW4	17.3	6.8-16.8	3.0-17.3
8200-MW5 (BKGRD MP)	22.6	12.1-22.1	3.0-22.6

[a] bgs = below ground surface.

Note: Monitoring points MPA, MPB, MPC, and MPG were installed by Parsons ES in Geoprobe® borings. Vent well VW2 and monitoring points MPD, MPE, and MPF were installed by Parsons ES in auger borings. Monitoring wells FCMW88 and FCMW89 were installed by ICF Kaiser (1992). Monitoring wells 8200-MW1, -MW2, -MW3, -MW4, and -MW5 were installed by RUST (1994). VW3 was installed by Parker Excavating, Inc. (1996).

TABLE 3.2
INITIAL SOIL GAS CHEMISTRY (1996)
REMEDIAL ACTION PLAN
BUILDING 8200
FORT CARSON, COLORADO

Sample Location	Screen Depth (feet)	O_2 (%)	CO_2 (%)	Field TVH (ppmv)[a]	Laboratory TVH (ppmv)[b]
FCMW89(VW1)	9.5-24.5	3.0	7.4	6,200	21,000
8200-VW2	4.5-19.5	1.5	14.0	14,000	24,000
8200-VW3[c]	11.0	14.8	4.0	2,500	---[d]
8200-MPA	16.0	20.8	0.05	0	---
8200-MPA	19.0	20.8	0.05	2,000	---
8200-MPB[e]	15.5	---	---	---	---
8200-MPB[e]	20.0	---	---	---	---
8200-MPC[e]	15.0	---	---	---	---
8200-MPC[e]	23.0	---	---	---	---
8200-MPD	10.0	0.8	6.8	300	42
8200-MPD	18.0	0.9	5.3	>20,000	37,000
8200-MPE	7.0	6.8	5.2	46	---
8200-MPE	11.0	18.2	0.1	95	---
8200-MPF	12.0	0.0	6.6	20,000	48,000
8200-MPF[f]	16.0	---	---	---	---
8200-MPG	13.0	5.0	5.8	78	---
8200-MPG[e]	22.0	---	---	---	---
8200-MW1	5.8-15.8	4.1	3.8	2,200	---
8200-MW2	7.6-17.6	0.7	6.5	10,200	---
8200-MW3	4.1-14.1	0.0	9.1	200	80
8200-MW4	6.8-16.8	20.5	0.5	250	---
8200-MW5	12.1-22.1	19.8	1.4	260	---
FCMW88	14.5-29.5	8.4	4.0	65	---

a/ Total volatile hydrocarbon field screening results reported in parts per million, volume per volume.
b/ Laboratory total volatile hydrocarbon analytical results by EPA Method TO-3 referenced to jet fuel (molecular weight=156).
c/ 8200-VW3 soil gas sampled on January 24, 1997.
d/ --- = Not analyzed.
e/ Unable to obtain a soil gas sample due to impermeable soil conditions.
f/ Monitoring point screened interval was within perched groundwater.

TABLE 3.3
OXYGEN UTILIZATION AND FUEL DEGRADATION RATES
REMEDIAL ACTION PLAN
BUILDING 8200
FORT CARSON, COLORADO

Location-Depth (feet bgs) [a/]	Test Duration (hours)	0_2 Loss (%)	O_2 Utilization Rate [b/] (%/hour)	Fuel Degradation Rate (mg TPH/kg/year)[c/]
VW2 4.5-19.5	96	5.8	0.056	84
MPD-10	243	6.8	0.027	40
MPD-18	243	11.5	0.046	70
MPG-13	193	2.7	0.013	20

[a/] bgs = below ground surface.
[b/] Values based on best-fit lines.
[c/] mg TPH/kg/year = milligrams of total petroleum hydrocarbons degraded per kilogram of soil per year.

kg of soil can be degraded each year at this site. This estimate is based on an average air-filled porosity of approximately 0.045 liter per kg of soil, and a ratio of 3.5 mg of oxygen consumed for every 1 mg of fuel biodegraded. Actual degradation rates may exceed these estimates. Results from the *in situ* respiration test indicate that VW2 and MPD-18 screened intervals (which have significant contamination) have active microorganism populations. Biodegradation rates at the other two monitored locations (MPD-10 and MPG-13) may be slower because there is not as much contamination (organic substrate) available for the bacteria to biodegrade.

Over time, the biodegradation rates at Building 8200 may increase. At a few of the 110 Air Force sites where Parsons ES has completed extended bioventing pilot testing, biodegradation rates increased following initial testing. One explanation for this is that with a continuous source of oxygen, the microbial population may increase, resulting in higher consumption rates.

3.4 OXYGEN INFLUENCE/AIR PERMEABILITY

The depth and radius of oxygen increase in the subsurface resulting from air injection into the VW during pilot testing is the primary design parameter for expanded-scale bioventing system design. Optimization of expanded-scale and multiple VW systems require pilot testing to determine the volume of soil that can be oxygenated at a given flow rate and VW screen configuration.

Abbreviated air permeability tests were conducted at wells FCMW88, FCMW89 (VW1), and VW2. A 1-hour permeability test was performed at well FCMW88 to determine the feasibility of utilizing the well for air injection during future expanded-scale system installation. At an air injection flow rate of approximately 7.5 scfm at well FCMW88, and a blower pressure of 50 inches of water, no pressure response was measured at any of the monitoring locations during this test. Following the permeability test at FCMW88, oxygen influence was measured at MPF-12, MPE-7, MPD-10, and MPD-18. Results indicated a 1 percent increase in oxygen concentration at MPF-12 only. Based on the negligible pressure and oxygen influence observed from injecting at FCMW88, and the high blower pressure that was required, FCMW88 was not converted for use as an air injection VW during the pilot-scale system installation. A high pressure blower to be used during expanded-scale operation should be capable of providing sufficient air flow to monitoring well FCMW88.

Following oxygen influence measurements, air was injected into VW2 for 2.5 hours at an air injection flow rate of approximately 8.7 scfm and a blower pressure of 44 inches of water. No pressure response was measured at MPD-10, MPD-18, MPE-7, MPE-11, MPF-12, MPG-13, and FCMW88. Following the permeability test at VW2, oxygen influence was measured at MPG-13, MPF-12, MPE-7, MPD-10, and MPD-18. Results indicated oxygen concentration increases of 0.5 percent at MPG-13, 13.1 percent at MPF-12, 2.4 percent at MPE-7, 4.5 percent at MPD-10, and 0.0 percent at MPD-18.

Pressure response also was measured at MPs following 46 hours of air injection at FCMW89 (VW1) and VW2. At air injection flow rates of approximately 1 scfm at each of wells VW1 and VW2, and a blower pressure of 25 inches of water, no pressure response was observed at MPA (located 10 feet from VW1) or at any of the other MPs

TABLE 3.4
INFLUENCE OF AIR INJECTION AT VW2 ON MONITORING POINT OXYGEN CONCENTRATIONS
REMEDIAL ACTION PLAN
BUILDING 8200
FORT CARSON, COLORADO

Location	Distance From VW2 (feet)	Screen Depth (feet bgs)[a]	Initial O_2 [b] (%)	Final O_2 [c] (%)	Initial TVH [b] (ppmv) [d]	Final TVH [c] (ppmv)
MPD	14.6	18.0	0.9	5.8	3,000	430
MPE	18.1	7.0	6.8	6.2	0	330
MPF	31.1	12.0	0.0	0.0	20,000	10,000
MPG	30.5	13.0	5.0	7.2	34	280
FCMW88	48.9	14.5-29.5	8.4	20.5	65	160
8200-MW1	96.0	5.8-15.8	4.1	1.6	2,200	8,200
8200-MW2	114.7	7.6-17.6	0.7	0.0	10,200	12,800
8200-MW3	149.0	4.1-14.1	0.0	0.0	240	1,100

[a] bgs = below ground surface.
[b] Measurements taken during July 1996, prior to bioventing pilot testing.
[c] Measurements taken on January 24, 1997, following an undetermined injection period.
[d] Field measurement for total volatile hydrocarbons (TVH) in parts per million, volume per volume.

at the site. Due to the negligible pressure response at the site, an estimated soil gas permeability value could not be calculated. Pressure response will be measured again prior to expanded-scale system installation activities.

Because the permeability tests did not provide information that was useful in determining the expected radius of pressure influence, changes in soil gas oxygen levels were measured on January 24, 1997, following an extended period of air injection into VW2 using the extended pilot test blower unit. Results of this oxygen influence testing are presented in Table 3.4. This period of air injection produced slight increases in soil gas oxygen levels at MPD, MPG and FCMW88. Based on measured changes in oxygen levels, it is anticipated that the radius of influence for a long-term bioventing system at this site will exceed 50 feet at depths corresponding to the more permeable sandy clay lenses (intermittently from 13 to 20 feet bgs near VW2); and 25 feet at all other depths. Within the less permeable fine grained soils, oxygen will likely diffuse from the permeable zones into the less permeable soils. Prior to installing the expanded-scale system at Building 8200, a soil gas sampling event will be performed at the site to verify the RI. Soil gas monitoring will be conducted prior to the expanded-scale system installation to better define the effective treatment radius.

3.5 POTENTIAL AIR EMISSIONS

The long-term potential for VOC air emissions from expanded-scale bioventing operations at this site is considered low because of the age and type of the site contaminants (greater than 5 years, and primarily diesel fuel); the very low air injection flow rates (5 scfm per VW); and the concrete cover. Air emissions should be minimal because accumulated vapors will move slowly outward from the air injection points and will be biodegraded as they move horizontally through the soil.

Air emissions monitoring was conducted during pilot-scale system startup at four locations using a GasTech® total volatile hydrocarbon analyzer sensitive to 1 ppmv volatile hydrocarbons. Because the potential for air emissions is highest during the initial hours of injection, and because no TVH emissions were detected, the long-term emission potential is considered low.

3.6 RECOMMENDATION FOR EXPANDED-SCALE BIOVENTING

Based on the extent and variable depth of petroleum contamination at the site, and the exuberant costs associated with traditional excavation and treatment/disposal methods, USAEC has provided funding through AFCEE for the design and installation of an expanded bioventing system that will remediate the most contaminated vadose and smear zone soils associated with Building 8200. USAEC and AFCEE have retained Parsons ES to continue bioventing services at Fort Carson and to complete the design and installation of an expanded bioventing system. Although the bioventing pilot test data indicates that the soils at the site are somewhat impermeable and that biodegradation rates are slow, *in situ* bioventing is considered the most efficient and cost-effective treatment alternative. It is anticipated that injected air will travel through the same preferential flow paths that much of the contamination migrated through. Additionally, long-term air injection may dry out the local soils enough to eliminate the limited amount of perched groundwater, thereby reducing the potential for further plume migration. Based on the initial pilot test results, available analytical data, and information from the recent tank removal project, Parsons ES has prepared an expanded-scale upgrade design that will employ the three existing VWs and four additional VWs. Six additional MPs also will be installed to ensure that oxygen is being delivered to contaminated soils and to further define the FAE of contamination. Section 4 provides details on the design, construction, and operation of the expanded system. A design package has been prepared for construction of the system and is included in Appendix A of this RAP.

SECTION 4

EXPANDED BIOVENTING SYSTEM

The purpose of the expanded bioventing system is to provide oxygen to stimulate aerobic biodegradation of vadose zone and unsaturated smear zone soil contamination present near the former USTs and associated fuel pump islands at Building 8200. The full areal extent (FAE) of smear zone contamination has not yet been defined. Therefore, future remedial action may be necessary in areas outside the targeted remedial zone. The three existing VWs and four additional air injection VWs will be used to provide oxygen to oxygen-depleted, unsaturated, contaminated soils at the site. Up to six additional MPs will also be installed to monitor oxygen delivery to contaminated soils. System design details are provided in Appendix A.

4.1 OBJECTIVES

Following its installation, the primary objectives for the expanded bioventing system will be to:

- Optimize the system to fully aerate the unsaturated subsurface in areas at the site targeted for bioventing remediation (vadose zone and smear zone soils in the immediate vicinity of the former USTs and fuel pump islands);
- Reduce the existing contaminant levels to below acceptable regulatory cleanup guidelines [CDPHE (1995) RAC II levels of 50 mg/kg total BTEX and 250 mg/kg TPH];
- Provide the most cost-effective remediation alternative for the site.

4.2 BASIS OF DESIGN

Site investigation data, tank removal information, pilot test data, and experience at other bioventing sites provided the main elements of the basis of design for expanding the bioventing system at Building 8200. The expanded system is designed to provide oxygen to intervals of significant soil contamination in the immediate vicinity of the former USTs and fuel pump islands, including vadose zone and smear zone contaminated soils. Site investigations conducted to date have not fully defined the extent of soil contamination. Therefore, the design includes installation of several additional MPs to better define the FAE of contamination at this site.

Pilot test data, such as operating air flow rates, injection pressures, and oxygen RI, were considered during design development. These data were considered in the spacing of VWs and sizing of an expanded-scale blower system. In addition to the pilot test data from the site, experience at other sites with similar soil types was considered in design development.

The significant design parameters and considerations for the air injection system are as follow:

- A RI of 25 feet was used, resulting in the spacing of VWs 50 feet apart. A soil gas sampling event will be performed prior to the installation of the expanded-scale system to verify the RI.

- An air injection pressure of 100 inches of water was assumed in sizing the expanded-scale bioventing blower. This is not consistent with pressures observed during the pilot test, however, higher pressures are expected due to the modified VW design.

- An air injection flow rate of 5 scfm per VW was assumed based on experience at other sites.

The expanded-scale design incorporates the existing pilot test blower at Building 8200 to continue to provide air to horizontal VW3, installed during the tank removal project. A new 6.0 HP regenerative blower will be installed at the site to provide air to the two VWs used for the pilot test (VW1 and VW2), and to three additional vertical VWs (VW4, VW5, and VW6) to be installed within contaminated soils near three of the pump islands. Monitoring well FCMW88 also will be converted for use as a VW.

The locations of six additional MPs were selected to provide information on the extent of vadose zone contamination, to be useful in evaluating the magnitude of contaminant reduction through soil gas sampling, and to provide important oxygen RI data. Several of the proposed MPs will be located in areas outside the design RI.

4.3 SYSTEM DESIGN

The proposed upgrade of the existing bioventing system at Building 8200 will incorporate the existing VWs (VW1, VW2, and VW3) and four additional VWs. Six new MPs also will be constructed to monitor soil gas at the site. The additional VWs will be installed to ensure that oxygen is introduced throughout the area of identified soil contamination near the pump islands. The new "nested" VWs will be constructed with two separate PVC casings constructed within each VW borehole to facilitate air flow through the less permeable clay interval. Each new VW casing will be 2 inches in diameter and will be screened with 0.040-inch slot PVC screen from approximately 4 to 9 feet bgs, or from 11.0 to 16.0 feet bgs. A 1.5-foot thick interval of bentonite pellets will be placed between the upper and lower screened intervals. Figure 4.1 shows the proposed locations of the existing and new VWs and MPs. Trenchline configuration and other design details are included in the design package provided in Appendix A.

The VWs will be manifolded using 1-inch-diameter PVC as the conduit from the new blower to the proposed VWs for the injected air. The piping will be connected to the new 6.0-HP regenerative blower and will be set at a depth of 18 inches beneath the ground surface. The existing header piping for VW1 and VW2 will be rerouted to the

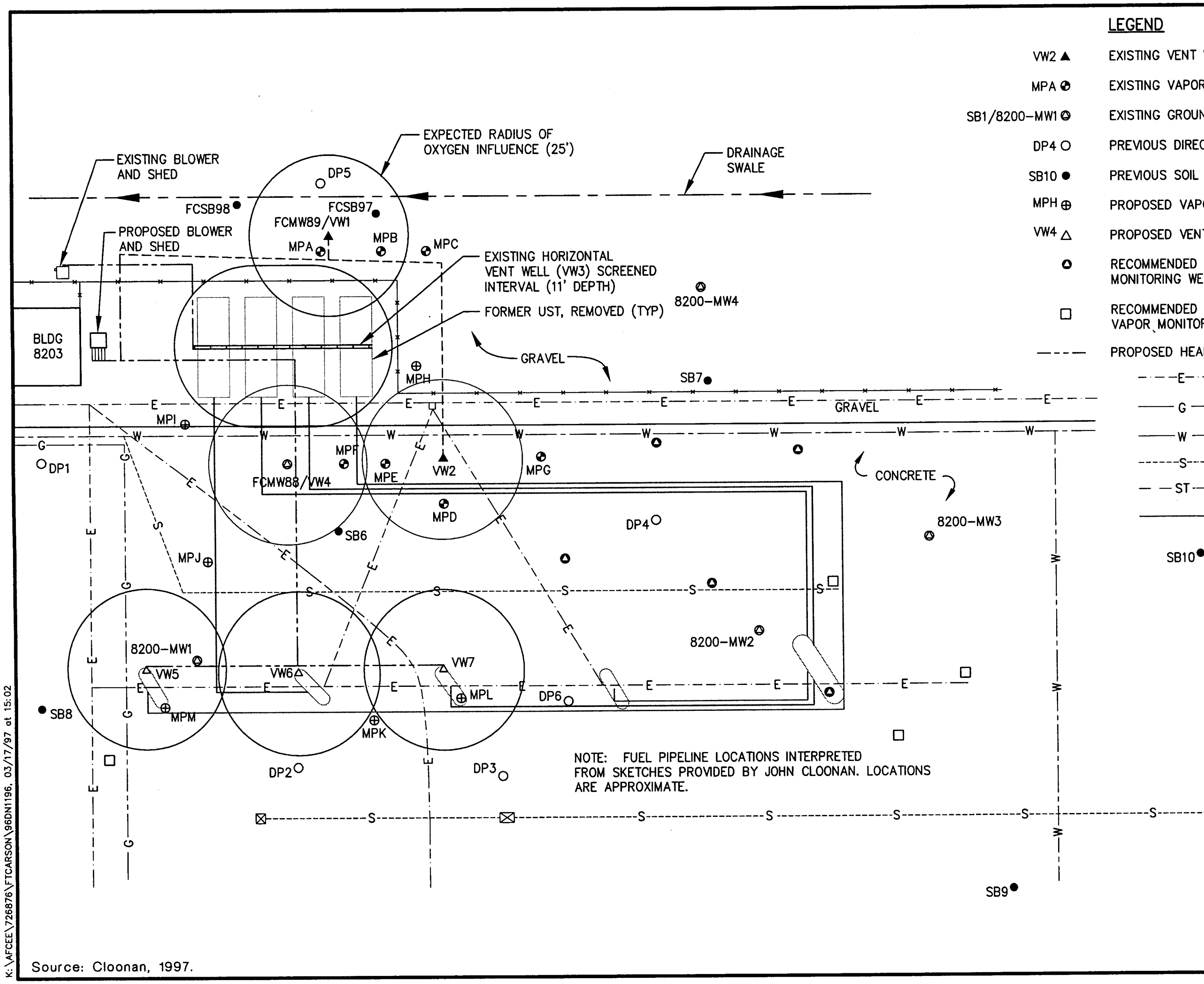


FIGURE 4.1

PROPOSED EXPANDED-SCALE BIOVENTING SYSTEM CONFIGURATION

Remedial Action Plan
Building 8200
Fort Carson, Colorado

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

new blower system. The existing blower will be used to provide air injection to VW3; and to the new deeper VW screened intervals, if expanded system operation monitoring indicates that a lower air injection pressure is necessary within the more permeable deeper zone. Separate, manual flow control valves and flow measurement ports will be included in the lines connecting each VW to allow independent adjustment of the air flow to each VW. The blower and valving will be housed in a weatherproof enclosure for protection from the elements and for security purposes.

Based on experience at other bioventing sites, an injection rate of 5 scfm at each VW should be sufficient to supply oxygen to the remaining contaminated soils and sustain *in situ* fuel biodegradation. The RI around each VW was estimated to extend greater than 25 feet based on the data collected during initial pilot testing. The proposed VW locations were selected to provide *in situ* treatment to the contaminated soils near the former pump islands and near the former tank pit, as shown on Figures 2.3, 2.4, and 2.5. A spacing of approximately 50 feet between VWs is planned (Figure 4.1).

Ambient air quality monitoring will be conducted during initial expanded-scale system operation to determine if air injection into the soil will displace volatile organic compounds (VOCs) into the atmosphere. Air quality monitoring will be conducted across the site on an hourly basis, at a minimum, during the first four hours of expanded-scale operation. Particularly, more extensive monitoring will be performed in the gravel-covered areas near the edge of the concrete. If VOCs are detected in ambient air at concentrations exceeding safety thresholds, the expanded-scale system operation will be discontinued. If VOCs are detected at lower concentrations, monitoring will continue until the detections dissipate. If VOCs persist in ambient air, corrective action (i.e. decreasing the air injection flow rate, identifying and blocking preferential flow channels to the surface) will be taken. If these corrective actions are performed and VOCs still persist in ambient air, the system operation will be temporarily discontinued and an alternative remedial approach will be recommended. Past experience at this site has shown that VOCs have not been driven into the atmosphere at detectable concentrations during bioventing operations.

Figure 4.1 also shows the location of nine additional exploratory soil boreholes that are recommended to further define the FAE of soil contamination at this site. Foothills Engineering Consultants is under contract to perform additional soil and groundwater sampling at the site during the spring of 1997. If, based on field observations during installation of the soil boreholes, significant vadose zone contamination is encountered, then VWs and MPs should be installed in these boreholes. If significant vadose zone contamination is not encountered in a soil borehole, a soil sample for laboratory analysis should be collected from near the saturated zone; and either a groundwater monitoring well should be installed, or the borehole should be abandoned.

4.4 PROJECT SCHEDULE

The following schedule for the bioventing system upgrade is contingent upon Fort Carson approval of the Work Permit Request.

Event	Start Date	End Date	Duration (working days)
Submit Draft RAP and Design Package to USAEC, AFCEE/ERT, and Fort Carson	NA	18 February 1997	NA
Review Period	18 February 1997	28 February 1997	9 days
Respond to Comments on Draft RAP	5 March 1997	17 March 1997	8 days
Submit Draft Final RAP to USAEC, AFCEE/ERT, Fort Carson, and CDPHE[a/]	NA	17 March 1997	NA
Draft Final Review Period	18 March 1997	21 March 1997	4 days
Respond to comments on Draft Final RAP	21 March 1997	24 March 1997	2 days
Final RAP and Design Package to USAEC, AFCEE/ERT, Fort Carson, and CDPHE	NA	24 March 1997	NA
Submit Work Permit (digging permit) Request	NA	3 March 1997	NA
Expanded System Installation/Startup	24 March 1997	4 April 1997	11 days
Oxygen Influence Monitoring	12 May 1997	12 May 1997	1 day
Complete Record Construction Drawings/ O&M Manual	7 April 1997	16 May 1997	30 days

[a/] Draft Final RAP to be submitted to CDPHE by Fort Carson.

4.5 SYSTEM OPERATION, MAINTENANCE, AND MONITORING

Following expanded bioventing system installation, Parsons ES engineers will perform system startup and optimization. An O&M plan and record system drawings will be prepared and submitted to USAEC, AFCEE, and Fort Carson.

4.5.1 System Operation

At startup of the expanded-scale system, it will be necessary to optimize the air injection rate and to ensure proper operation of the blower system. Flow rate optimization is accomplished by gradually increasing the flow rate to each VW until soil gas oxygen concentrations at all MP depth intervals reach a minimum concentration of approximately 5 percent. Oxygen levels in excess of 5 percent at the outer MPs may indicate that the volume of air passing through the soil exceeds the biological oxygen utilization rate. The blower will be checked to ensure that it is producing the required flow rate and pressure for air injection.

Following flow rate optimization, the system will run continuously and will require minimal maintenance as described below. Parsons ES has been contracted by USAEC and AFCEE to provide 1 year of system O&M support under Option 1 of the AFCEE Extended Bioventing Project. O&M support will include Parsons ES performing any system repairs should the bioventing system fail to operate properly.

4.5.2 System Maintenance

System maintenance requirements for the proposed bioventing system are minimal because the regenerative blower is virtually maintenance-free. The only recurring maintenance required is a monthly check by Fort Carson personnel of the air filter, which is generally replaced when the vacuum across the inlet filter reaches a vacuum reading 10 to 15 inches of water greater than the reading with a clean filter. The time period between filter changes is dependent on site conditions, and is typically every 3 to 6 months. The O&M manual will further detail maintenance requirements. Parsons ES is responsible for 1 year of maintenance support under Option 1 of the Extended Bioventing Project. Should the blower system give indications of an electrical or mechanical problem, such as a significant change in outlet pressure, abnormal noises from the blower, or system failure, during the first year of operation, Parsons ES will be responsible for repairing the system. Prior to mobilizing to the site, Parsons ES may request that a Fort Carson electrician verify that adequate power is being supplied to the blower motor. Once adequate power to the motor has been verified, Parsons ES will take the necessary actions to repair the blower system. Following the year of maintenance support by Parsons ES, Fort Carson will be responsible for system maintenance.

4.5.3 System Performance Monitoring

Routine monitoring of the bioventing system will include system checks of blower operation, including outlet pressures, inlet vacuum, and exhaust temperature every two weeks. These system checks will be performed by Fort Carson technicians.

To provide baseline data against which the progress of remediation can be evaluated, soil and soil gas samples will be collected by Parsons ES during installation of the expanded-scale bioventing system, and an *in situ* respiration test will be performed. These data will be used along with the previous data collected during the initial pilot testing to provide a basis for comparison in the future. "Point" respiration tests will be performed at two or more new MP intervals within the former pump islands that exhibit low oxygen concentrations. *In situ* respiration testing will be performed in accordance with the bioventing protocol procedures (Hinchee *et al.*, 1992)

Soil samples will be collected from all boreholes advanced during drilling activities for installation of the expanded-scale bioventing system components. Samples will be collected at 2.5-foot intervals, and will be screened in the field for organic vapors using a PID. One soil sample from each borehole will be sent to an analytical laboratory for analysis of BTEX by USEPA Method SW8020, and TEPH and TVPH by USEPA Method SW8015 modified. These samples will be collected from the most contaminated intervals in the boreholes advanced for the VWs and MPs.

Soil gas sampling will be conducted at all MPs and VWs prior to system startup to establish baseline oxygen, carbon dioxide, and TVH levels using field instruments. In addition, soil gas samples from five locations will be forwarded to Air Toxics Ltd. of Folsom, California for analysis of TVH-jf and BTEX by Method TO-3. The locations of these samples will be determined based on the field screening results. The five intervals exhibiting the highest TVH concentrations based on field instrument readings will be sampled for laboratory analysis.

System performance monitoring by Parsons ES under Option 1 of the Extended Bioventing Project will include *in situ* respiration testing during a site visit after 1 year of expanded-scale system operation. Soil gas samples will be collected from five of the same MPs sampled during the expanded-scale system and pilot test installations and analyzed for BTEX and TVH using USEPA Method TO-3. No soil sampling will be performed under Option 1 of the Extended Bioventing Project.

Prior to performing the 1-year respiration test and soil gas sampling, oxygen influence measurements will be recorded for all site MPs. The blower will then be turned off and an "area" respiration test will be started. Oxygen uptake will be monitored at the MPs for approximately 11 days to measure the rate at which soil gas oxygen concentrations decrease. These data will then be used to estimate current biodegradation rates and to evaluate the progress of contaminant removal and system effectiveness. No less than 45 days following system shut-down, soil gas samples will be collected for laboratory analysis. To ensure that the soil gas TVH levels have equilibrated with the soil (i.e., to ensure that 1-year data can be compared to initial soil gas data), a final respiration reading will be obtained prior to soil gas sample collection. As the fuel in the soil is degraded, the respiration activity of the indigenous microorganisms is reduced, and slower oxygen utilization rates may result. The use of oxygen utilization and soil gas chemistry as indicators of remaining contaminant concentration decreases the likelihood of premature closure soil sampling events.

System monitoring and *in situ* respiration test data will be analyzed to determine the progress of soil remediation. Estimates of contaminant reduction and time remaining to complete soil remediation to RAC II levels will be based on the data collected during the respiration tests (oxygen utilization rates), quantitative estimates of the long-term biodegradation rates, and decreases in soil gas concentrations. If soil gas data indicate that the soils have been sufficiently remediated, closure sampling may be recommended.

Fort Carson will be responsible for monitoring the performance of remediation after the initial year of expanded-scale operations, when Parsons ES's obligations will be completed. It is recommended that annual respiration testing and soil gas sampling be performed to evaluate the progress of remediation. In addition to these activities, monitoring the system pressure, vacuum, and temperature should be performed every 2 weeks.

SECTION 5

HANDLING OF INVESTIGATION-DERIVED WASTES

Cuttings and soils excavated from the air injection pipeline trenches will be screened in the field with a PID. If screening indicates that the soils are clean (i.e., soil with PID readings less than 25 ppmv above background, no petroleum odor, and no discoloration), they will be spread on the ground surface adjacent to the facility. If screening indicates that the soils are contaminated, they will be placed in US Department of Transportation (DOT) approved 55-gallon drums and disposed of in accordance with the policies of Fort Carson. It is anticipated that 19 cubic yards of soil cuttings will be generated during installation of the expanded-scale bioventing system. Fort Carson is responsible for final disposition of contaminated soil.

Decontamination of augers, sampling equipment, and all other items requiring decontamination will be performed at a temporary decontamination area set up at the site. Decontamination water will be placed in DOT-approved 55-gallon drums and temporarily stored at the site. After completion of drilling activities, the water will be disposed of by Fort Carson in accordance with the policies of the Fort.

SECTION 6

FORT SUPPORT REQUIREMENTS

The following support from Fort Carson is needed prior to the arrival of the drillers and the Parsons ES field team:

- Assistance in obtaining a digging permit (work permit).
- Provide a copy of any Fort soils management plan and/or sampling and analytical procedures plan.
- A potable water supply for well construction and decontamination activities.
- Provide for proper disposal of waste derived during drilling activities.

During expanded-scale bioventing, Fort Carson personnel will be required to check the blower system once every 2 weeks to ensure that it is operating properly, to record air injection pressures and temperatures, and to replace air filters, as needed. Parsons ES will provide a maintenance procedures manual and a training session.

1. If a blower stops working, notify Mr. Dave Teets or Mr. John Ratz of Parsons ES at (303) 831-8100, Major Ed Marchand of AFCEE at (210) 536-4364, or Mr. Gene Fabian of USAEC at (410) 612-6836.
2. Arrange site access for a Parsons ES technician to conduct respiration testing and soil gas sampling approximately 1 year after expanded-scale system installation and start up.

SECTION 7

POINTS OF CONTACT

Mr. John Cloonan
HQ, Fort Carson
Attn: AFZC-ECM-EC
Building 302
Fort Carson, CO 80913-5000
Phone: (719) 526-8004
Fax: (719) 526-2091

Mr. Gene Fabian
US Army Environmental Center
Attn: SFIM-AEC-ETD
Bldg E4430
APG-EA, Maryland 21010-5401
Phone: (410) 612-6847
Fax: (410) 612-6836

Major Edward Marchand
AFCEE/ERT
3207 North Road, Building 532
Brooks AFB, TX 78235-5363
Phone: (210) 536-4364
Fax: (210) 536-4330

Mr. Dave Teets, Site Manager
Mr. John Ratz, Project Manager
Parsons Engineering Science, Inc.
1700 Broadway, Suite 900
Denver, CO 80290
Phone: (303) 831-8100
Fax: (303) 831-8208

SECTION 8

REFERENCES

Colorado Department of Labor and Employment, Oil Inspection Section. 1995. *Storage Tank Facility Owner/Operator Guidance Documents*. July 1.

Cloonan, John, 1997. Fascmile Communication. Interpreted drawing of fuel pipeline locations at Building 8200. Prepared by John Cloonan (from Army Corps of Engineer design drawings). March 11.

Hinchee, R.E., S.K. Ong., R.N. Miller, D.C. Downey, and R. Frendt. 1992. *Test Plan and Technical Protocol for a Field Treatability Test for Bioventing*. Prepared for USAF Center for Environmental Excellence. May.

ICF Kaiser Engineers. 1992. Field notes (boring logs and well construction details) for well installation, Building 8200, Fort Carson, Colorado.

Madsen, Clint. 1996. Personal Communication. Phone conversation between Clint Madsen (Parker Excavating, Inc.) and David Teets (Parsons ES), December 3, 1996.

Parker Excavating, Inc. 1997. Facsimile Communication. Building 8200 tank removal information. January 7, 1997.

Parsons Engineering Science, Inc. 1996. *Draft Bioventing Pilot Test Work Plan for Building 8200, Fort Carson, Colorado*. June.

RUST Environment & Infrastructure. 1994. *Draft Site Assessment Report for Multiple Underground Storage Tanks, Fort Carson, Colorado*. October.

APPENDIX A

DESIGN PACKAGE

CONSTRUCTION DRAWINGS FOR

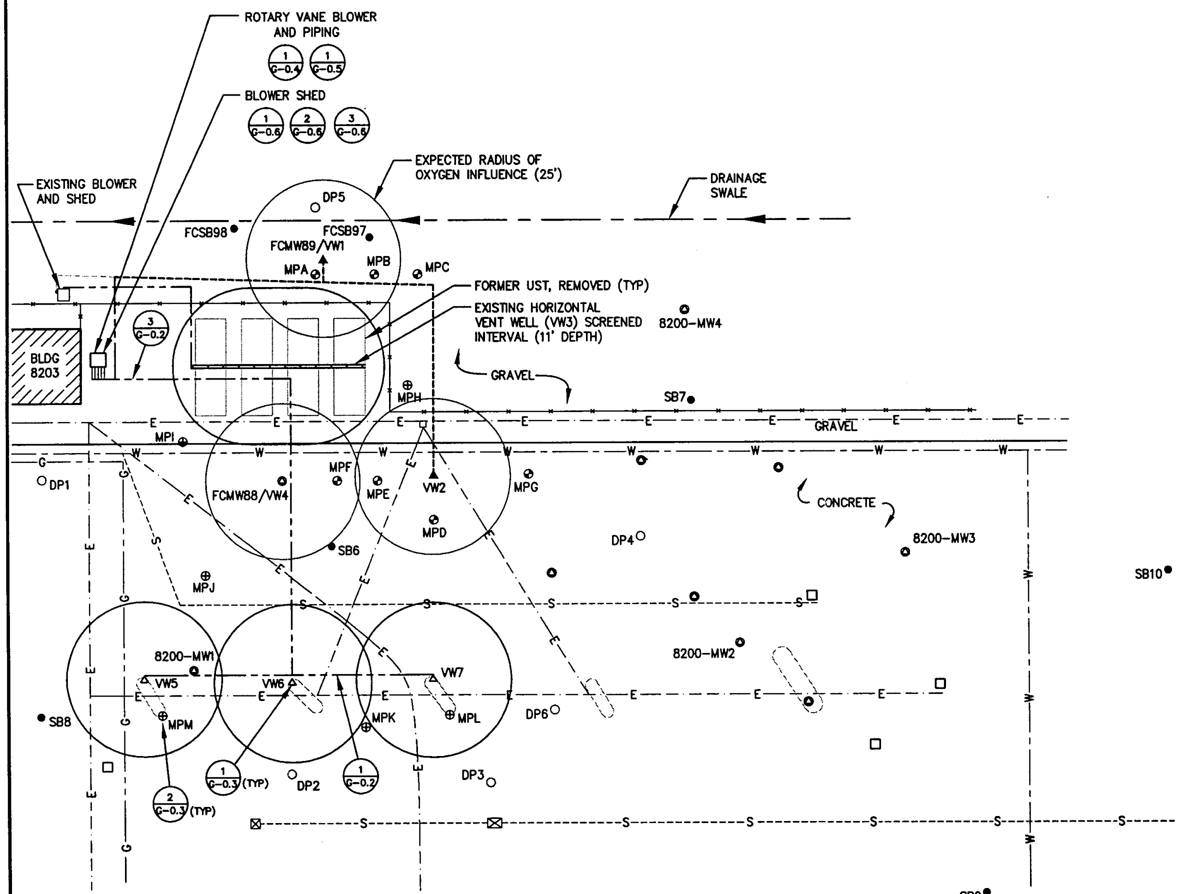
EXPANDED BIOVENTING SYSTEM BUILDING 8200 FORT CARSON

PREPARED FOR

AFCEE AND USAEC

MARCH 1997

DRAWING INDEX



SITE LAYOUT

SCALE: 1" = 40'

Job No. 726876.73340			
Designed DBT			
Drawn JH			
Checked DBT	3/12/97		
Reviewed CBK	3/17/97		
Approved JWK	3/17/97		
Reg No	3/12/97	2	65% DESIGN
Date	Date	Rev	Description	By

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado (303) 831-8100

AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE (AFCEE)

EXPANDED BIOVENTING SYSTEM
BUILDING 8200
FORT CARSON

TITLE SHEET AND SITE LAYOUT

DRAWING NO G-0.1 REV 1

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ABBREVIATIONS

AIJ	AIR INJECTION
APPROX	APPROXIMATE
ASTM	AMERICAN SOCIETY FOR TESTING AND MATERIALS
&	AND
@	AT
BLDG	BUILDING
CBM	CENTER BACK MOUNT
DIA	DIAMETER
E	ELECTRICAL
eg	FOR EXAMPLE
FPT	FEMALE PIPE THREAD
FT	FOOT
G	GAS
GALV	GALVANIZED STEEL
HDPE	HIGH-DENSITY POLYETHYLENE
LM	LOWER MOUNT
MAX	MAXIMUM
MIN	MINIMUM
MP	MONITORING POINT
MPT	MALE PIPE THREAD
NO, #	NUMBER
NPT	NATIONAL PIPE THREAD
NTS	NOT TO SCALE
OC	ON CENTER
OD	OUTSIDE DIAMETER
PVC	POLYVINYL CHLORIDE
PSI	POUNDS PER SQUARE INCH
REF	REFERENCE
SCH	SCHEDULE
S	SEWER
SPVC	SLOTTED POLYVINYL CHLORIDE
ST	STORM SEWER
ST STL	STAINLESS STEEL
TYP	TYPICAL
UE	UNDERGROUND ELECTRIC
UST	UNDERGROUND STORAGE TANK
VW	VENT WELL
W	WATER
W/	WITH
WWF	WELDED WIRE FABRIC

SYMBOLS

8200-MW1	EXISTING GROUNDWATER MONITORING WELL
MPA	EXISTING BIOVENTING MONITORING POINT
VW1	EXISTING VENT WELL
SB6	PREVIOUS SOIL BORING
DP1	PREVIOUS DIRECT PUSH SOIL/WATER SAMPLING LOCATION
MPH	PROPOSED BIOVENTING MONITORING POINT
VW4	PROPOSED VENT WELL
	RECOMMENDED SOIL BORING/ POTENTIAL VENT WELL
	RECOMMENDED SOIL BORING/ POTENTIAL MONITORING POINT
	PROPOSED HEADER PIPE TO VENT WELL
	EXISTING HEADER PIPE TO VENT WELL
	FENCE

SECTION DESIGNATION — SECTION NAME

SECTION CUT (A / X)

SCALE: NTS

DRAWING OF ORIGIN — SCALE

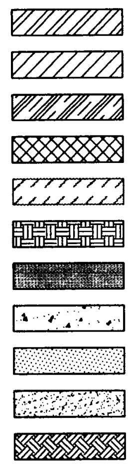
DETAIL NO — DETAIL NAME

DETAIL DESCRIPTION (1 / X)

SCALE: NTS

DRAWING OF ORIGIN — SCALE

MATERIAL LEGEND

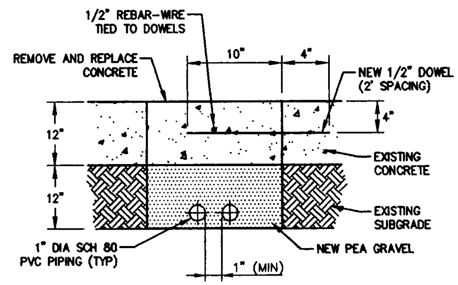


PIPE MATERIAL

GALV	GALVANIZED STEEL
PVC	POLYVINYL CHLORIDE
SPVC	SCREENED POLYVINYL CHLORIDE

PIPE SERVICE

AIJ	AIR INJECTION



CONCRETE REPLACEMENT DETAIL (1 / –)

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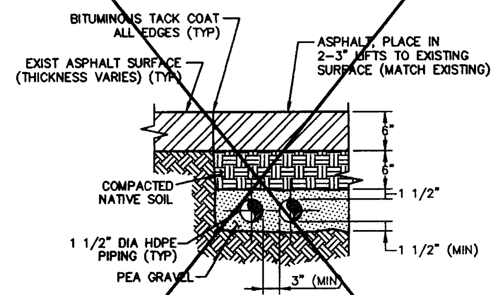

ASPHALT REPLACEMENT DETAIL (2 / –)

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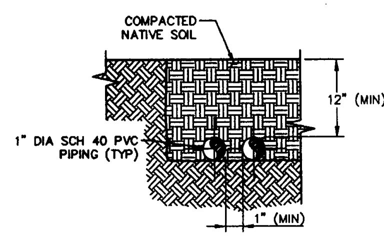

SOIL COVER REPLACEMENT DETAIL (3 / –)

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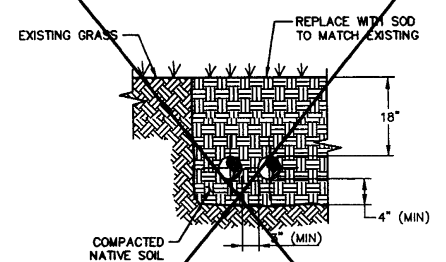

GRASS COVER REPLACEMENT DETAIL (4 / –)

SCALE: NTS

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Designed DBT			
Drawn MW			
Checked DBT	2/13/97		
Reviewed	2/17/97		
Approved	2/17/97		
Reg No	1	2/17/97	65% DESIGN
Date	Rev	Date	Description	By

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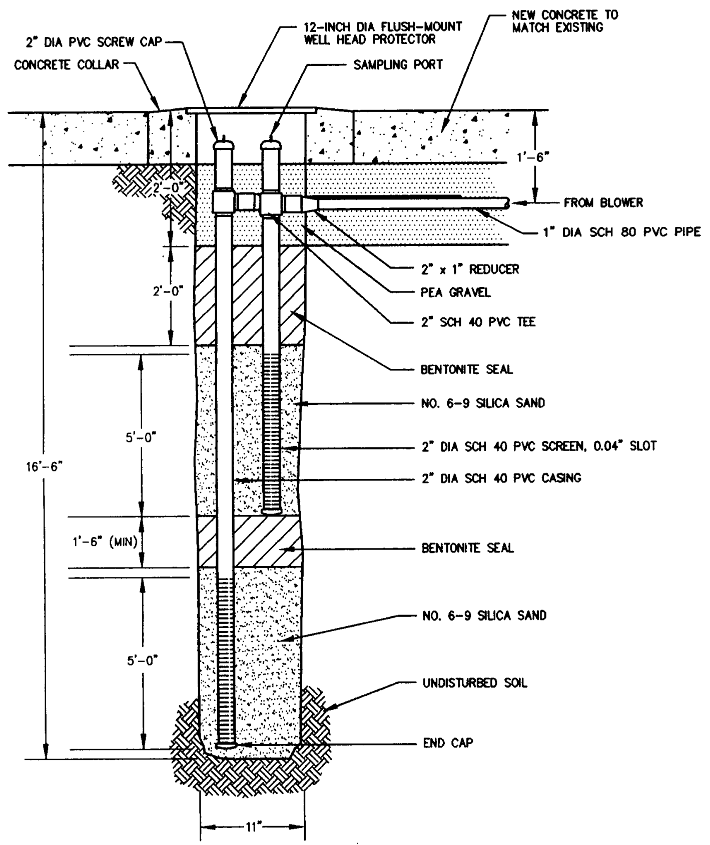
AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE (AFCEE)

EXPANDED BIOVENTING SYSTEM
BUILDING 8200
FORT CARSON

LEGEND AND STANDARD TRENCH DETAILS

DRAWING NO G-0.2 REV 1



1 VENT WELL (VW) DETAIL

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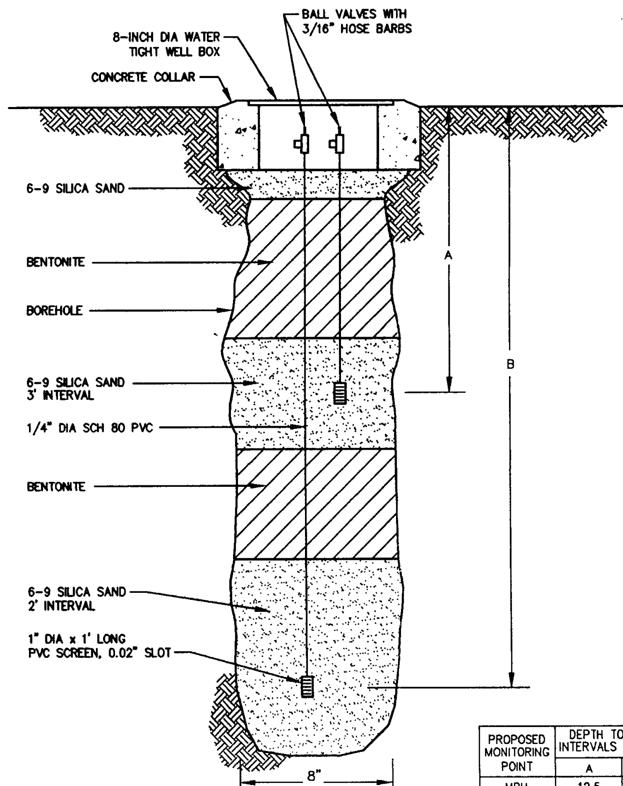

PROPOSED MONITORING POINT	DEPTH TO SCREEN INTERVALS (ft bgs)a/	
	A	B
MPH	12.5	17
MPI	12.5	17
MPJ	11.5	16
MPK	11.5	16
MPL	5.5	15
MPM	5.5	15

a/ ft bgs = feet below ground surface.

2 MONITORING POINT (MP) DETAIL

SCALE: NTS

Job No. 726876.73340				
Designed DBT				
Drawn MW				
Checked DBT	2/17/97			
Reviewed	2/17/97			
Approved	2/17/97			
Reg No	1	2/17/97	RECORD DRAWING	
Date	Rev	Date	Description	By

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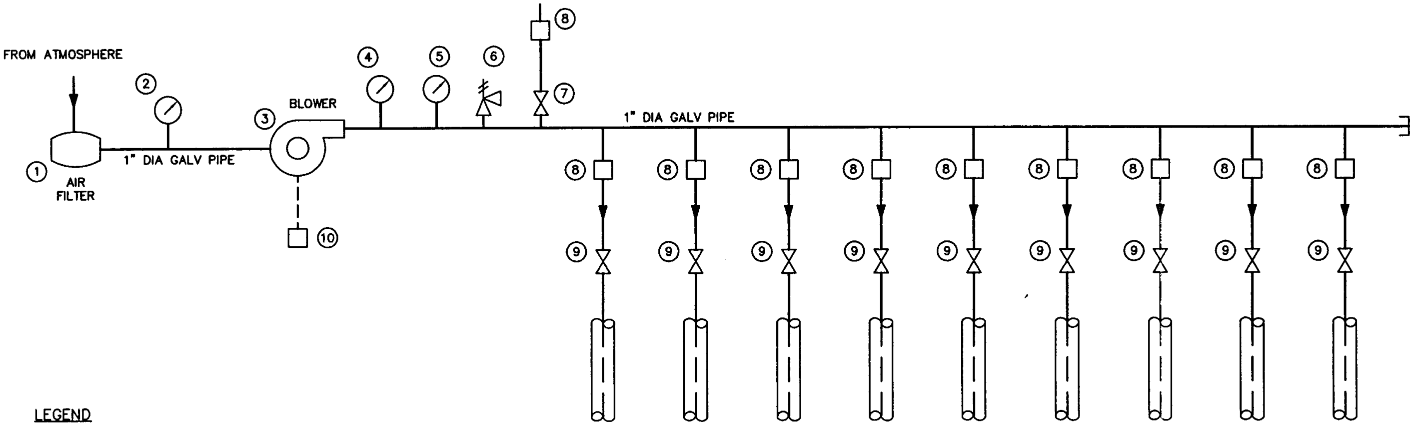
AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE (AFCEE)

EXPANDED BIOVENTING SYSTEM
BUILDING 8200
FORT CARSON

VENT WELL AND MONITORING POINT STANDARD DETAILS

DRAWING NO G-0.3 REV 1



<u>LEGEND</u>

1. INLET AIR FILTER – GAST® AJ126D, REPLACEMENT ELEMENT AJ134E
2. VACUUM GAUGE, GAST® AA640 2" DIA., 0–30" MERCURY 1/4" NPT, LM
3. BLOWER – GAST® 5.0 HP 6066–P122–T339, 53 CFM AT 5 PSI
4. TEMPERATURE GAUGE – ASHCROFT, 0–250°F, 1/2" NPT, CBM (Part No. 2A606 FROM GRAINGER)
5. PRESSURE GAUGE – GAST® AA644B, 2" DIA., 0–30 PSI, 1/4" NPT, LM
6. AUTOMATIC PRESSURE RELIEF VALVE – GAST® AA307, ADJUSTABLE, 2–25 PSI PRESSURE
7. MANUAL PRESSURE RELIEF (BLEED) VALVE – 1" GATE
8. FLOW MEASURING PORT FITTED WITH PLUG (1/4"x 1/8" NPT BRASS REDUCING BUSHING, 1/8" NPT BRASS PLUG)
9. FLOW CONTROL VALVE – 1" GATE
10. STARTER AND FUSED DISCONNECT SWITCH

1/– BLOWER PIPING AND INSTRUMENTATION DIAGRAM

SCALE: NTS

Job No. 726876.73340				
Designed DBT				
Drawn MW				
Checked				
Reviewed	3/17/97			
Approved	3/17/97			
Reg No	2	3/12/97	65% DESIGN	
Date	Rev	Date	Description	By

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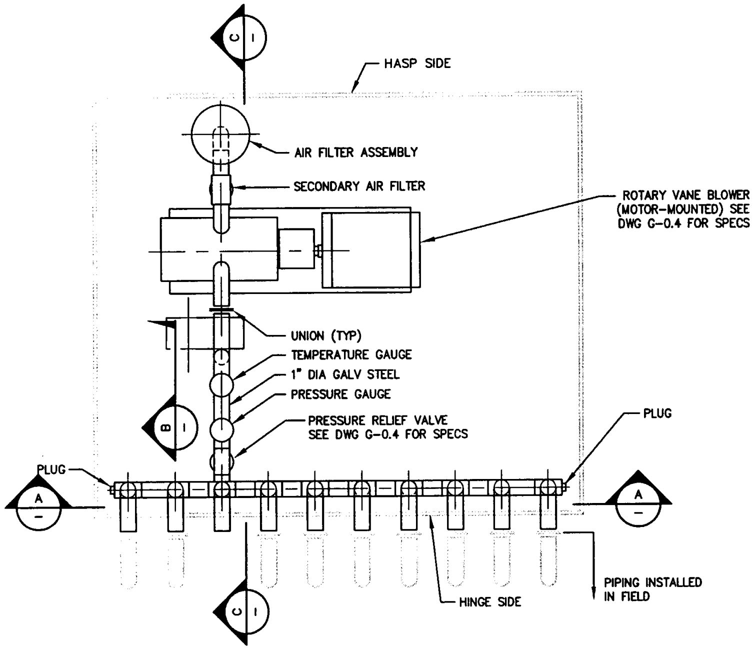
AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE (AFCEE)

EXPANDED BIOVENTING SYSTEM
BUILDING 8200
FORT CARSON

BLOWER P & ID

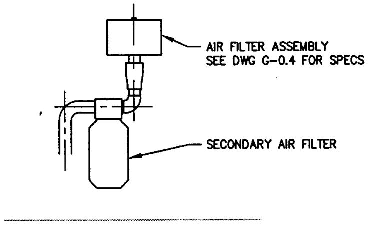
DRAWING NO G-0.4 REV 1

NOTES:
1. SHOP CORE HOLES TO PIPING DIMENSIONS
2. ALL PIPING 1" DIA. GALVANIZED STEEL, UNLESS OTHERWISE NOTED
3. SEE DRAWING G-0.6 FOR BLOWER BUILDING DETAILS



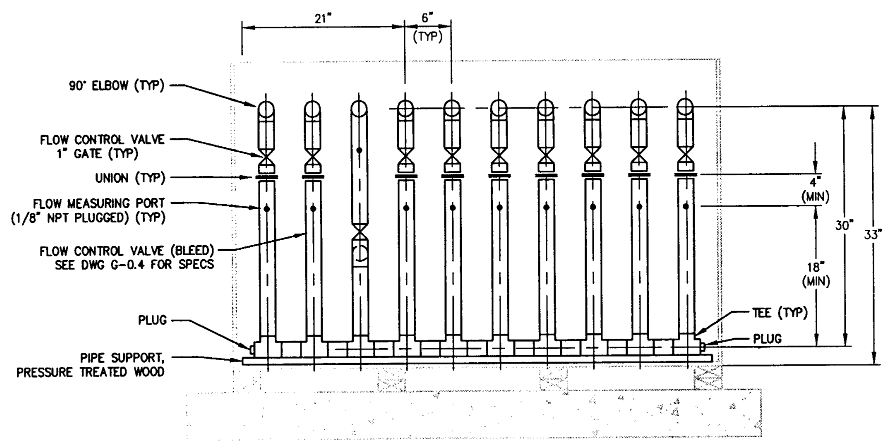
1 BLOWER PIPING LAYOUT PLAN DETAIL

3/4" = 1'-0"



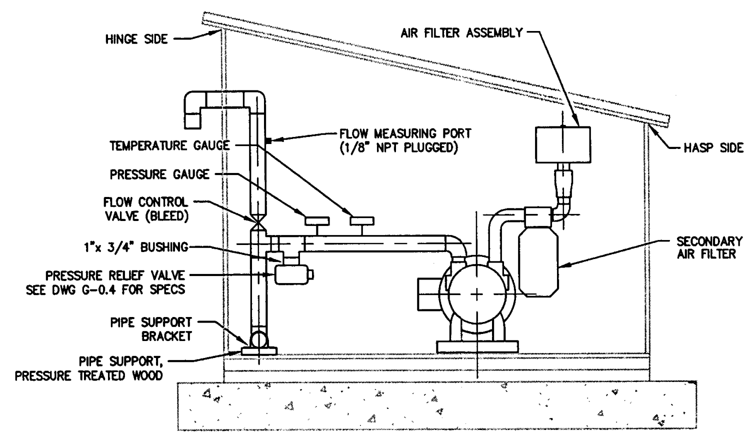
B BLOWER INLET PIPING SECTION

3/4" = 1'-0"



A MANIFOLD DETAIL SECTION

3/4" = 1'-0"



C BLOWER OUTLET PIPING SECTION

3/4" = 1'-0"

Job No. 726876.73340				
Designed DBT				
Drawn MW				
Checked DJST	3/13/97			
Reviewed GBL	3/17/97			
Approved JGL	3/17/97			
Reg No	2	3/12/97	65% DESIGN	
Date	Rev	Date	Description	By

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BUILDING 8200
FORT CARSON

BLOWER PIPING LAYOUT DETAIL

DRAWING NO G-0.5 | REV 1

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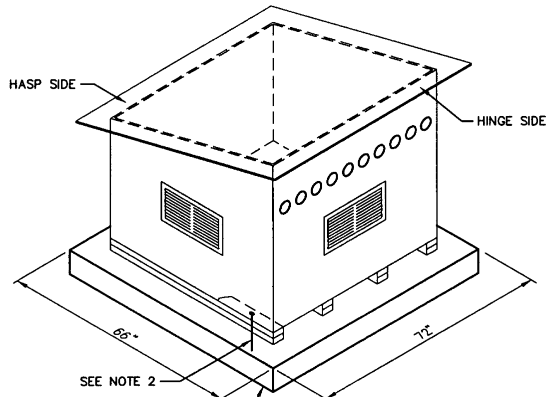
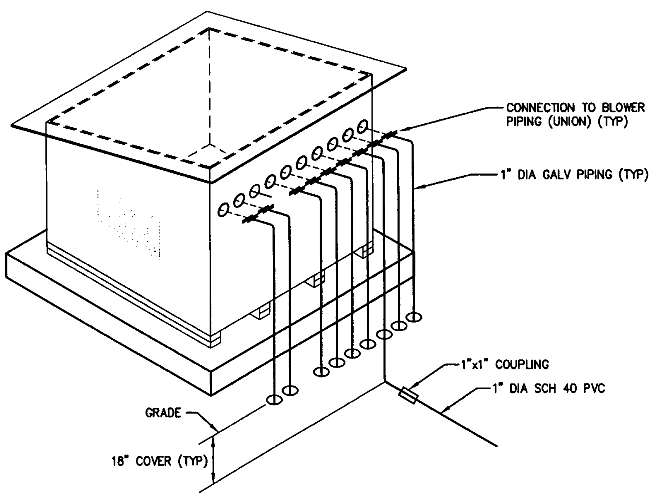


NOTES:
1. BUILDING INSTALLED CENTRAL ON CONCRETE SLAB WITH ORIENTATION AS SHOWN
2. BLOWER SHED SECURED TO CONCRETE SLAB AT LOCATIONS BY THRU BOLTING. WITH 3/8"x 6" LONG ST STL WEDGE ANCHOR BOLTS

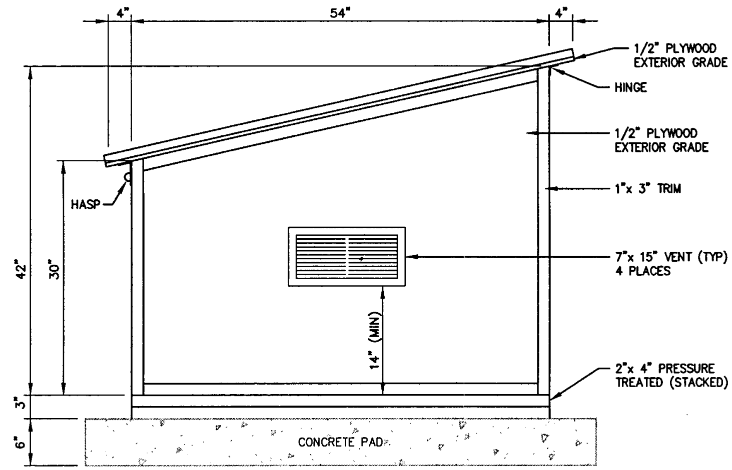
1/– BLOWER SHED FIELD INSTALLATION DETAIL

NOT TO SCALE

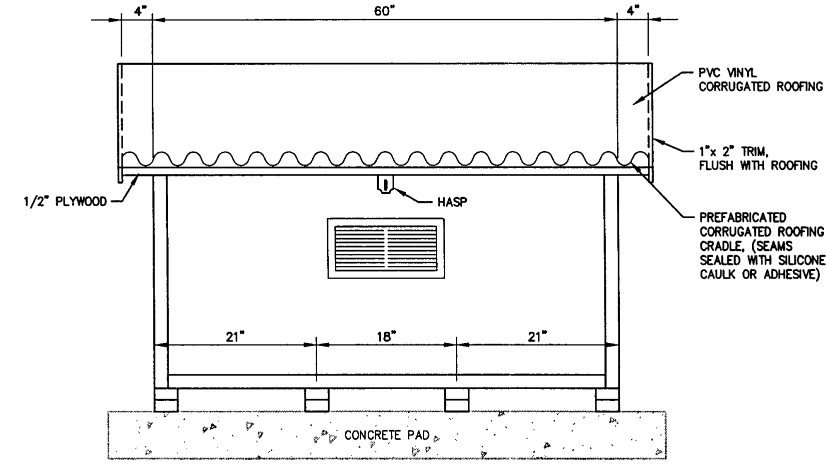


2/– TYPICAL MANIFOLD DISCHARGE PIPING LAYOUT

NOT TO SCALE



SIDE ELEVATION



FRONT ELEVATION

NOTES:
1. 2"x 2" FRAME CONSTRUCTION
2. FLOOR CONSTRUCTED OF 3/4" EXTERIOR GRADE PLYWOOD
3. ROOF CONSTRUCTED OF 1/2" EXTERIOR GRADE PLYWOOD COVERED WITH PVC VINYL CORRUGATED ROOFING

3/– BLOWER SHED CONSTRUCTION DETAIL

3/4" = 1'-0"

Job No. 726876.73340			
Designed DBT			
Drawn MW			
Checked DBT	3/12/97		
Reviewed	3/12/97		
Approved	3/12/97		
Reg No	2	3/12/97	65% DESIGN
Date	Rev	Date	Description / By

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AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE (AFCEE)
EXPANDED BIOVENTING SYSTEM
BUILDING 8200
FORT CARSON

BLOWER SHED FIELD INSTALLATION DETAIL AND BLOWER SHED CONSTRUCTION DETAILS

DRAWING NO G-0.6 | REV 1

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